Introduction to Engineering Seismology
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Lecture – 55
Seismotectonics of India - 2

Welcome. So we will continue our engineering seismology lectures. So, last class we have been discussing about the seismicity on the seismotectonic of India. So, we have discussed like several the deadly earthquakes so the great earthquakes like above magnitude 8 with respect to the northern part of boundary, northeastern part of boundary as well as northwestern part of boundary and also in peninsular India.

Okay so this is what we discussed starting from Killari earthquake so all those things we discussed. So, we further discussed about the formation of the India, Indian mountain basically, the tectonics. So earlier we have seen that India was an Island which was moving in the speed of 20 centimeter per year then it heat the Eurasian Plate where the speed reduced considerably.

So now it is pushing the Eurasian Plate in the speed of 5 centimeter per year and the Eurasian Plate is basically pushing the Indian Plate in the speed of 3.2 centimeter per year. So both of them basically pushing each other so there is a formation of mountain that is what we discussed. So, the initially the subduction action was the predominant in the northern part of the plate boundary.

So later after formation of these Himalayan and all those things, so it is become an active crustal region. So there are two types of earthquakes are possible. One is that active crustal zone earthquakes and subduction zone earthquakes. So the subduction zone earthquake remains the same particularly on the western side, the Sumatra and other places are there, but as I told you that part we are not going to concentrate on seismic hazard assessment of the Indian part.

But if you want to take a tsunami hazard assessment you need to consider that. So our discussion will only restricted to hazard analysis which is required for design of buildings and important structures. So we are not going to concentrate on the subduction zone in the

Sumatra region, but we will be concentrating on the other subduction zone earthquakes which is like a very deep, like close to like 150 to 200, 300 kilometer deep earthquakes and then active crustal earthquake which is formation of the mountain and rupturing due to heating up Indian Plate and Eurasian Plate that we will be considering.

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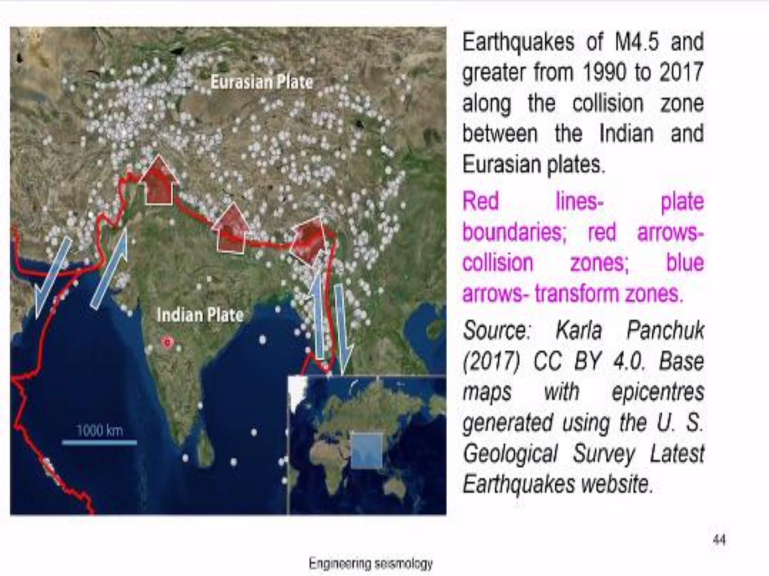

We have also seen that, so basically apart from this active region in the Indian Plate boundary we also understand that the eastern and western part of plate particularly where it interacting with the Burmese Plate and interact with this side with I think it is on Antarctica or the Arabian Plate kind of things okay where the Pakistan side. So these two side actually where you can expect a transformed boundary behavior.

You can see this is actually. So this is the pushing where the active crust and subduction they are taking place here the transformed action is taking place. So these three actions need to be modeled or accounted when you do any hazard estimation which is going to affect because of these three actions in this region basically up to this region. So, further if you come down your south you have seen there are earthquakes here, earthquakes here so earthquakes here and there are earthquake here.

But these earthquakes generally are intraplate in earthquakes in nature. So these earthquakes basically caused these are all the earthquake due to the activation of the local seismic source. Sso due to bending action of this plate because when you are going at a speed and heating so there is a bending takes place that bending basically create the additional force which is activate some of the joins or the geological materials in this region, central and the southern part of India.

So, those also causes a earthquake. So today class what we are going to do basically, we are going to discuss more about this kind of understanding of the seismotectonics in India in detail apart from the talking about the overall this one. So this information as I told you that very long back so the recording of earthquakes are very poor in India. So because of that like understanding of several things was very challenging.

So before 2010 very limited literatures was available on understanding of the plate tectonics of the India. So Indian Plate, intraplate, interplates joins all those things are very, very difficult, but after establishing the many digital seismic session the data were available to scientist. Scientist are recently start publishing more and more paper which is described the seismotectonics of this region.

So, I am going to talk about some of those studies, so why those studies are very important because if you want to take appropriate model, simulation model, fault type depth of the earthquake, what magnitude is experienced, what is the VP velocity, VS velocity. So you need all these literatures as your study. So I give you a glimpse of some of the study which is I gone through and prepared for the class.

But you need to understand that any region before starting hazard analysis you have to do this kind of systematic study. So what I am showing was a typical cases it does not mean that the same thing only applicable. You should do as on that date when you are starting hazard analysis what are the studies are available, what are information are available. As I told you that VP and VS velocity even though we discussed the range okay in the wave characteristics.

A particular region the VP velocity will be unique, VS velocity will be unique that is the velocity you should use to estimate your distance arrival. So the distance of the epicenter, so which will give you the accurate prediction of the locating earthquake, depth of earthquake, also all those information will be useful. So those are all the studies, some of the studies what done on seismotectonic, I am going to present here.

So these studies most of them were taken from the literature from the journal papers. I have also given here respective references in the bottom of the each discussion.

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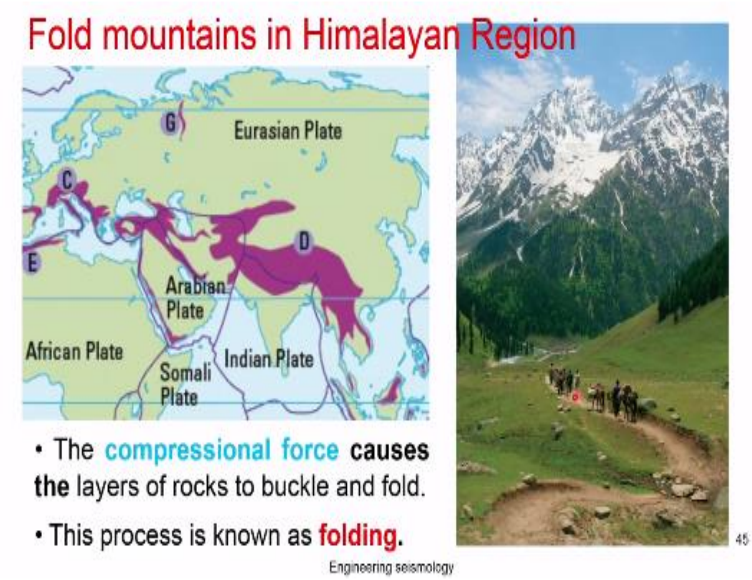

So, the Himalayan belt as we told that the both of them are heating and forming a mountain. So the mountain what type of mountain it forms basically. So the Himalayan belt forms a fold mountain. So because the compressional force caused by the layer of the rock buckle and fold so that process is called as a folding, that folding mountain is basically formed. So this is the map which shows a folding mountain in the different part of the continent.

So you can see entire globe like, so we have a very large percentage of the share, so you can typically see here how the fold, so you can see this is a basically a one layer then it is folded to here and then it folded to here.

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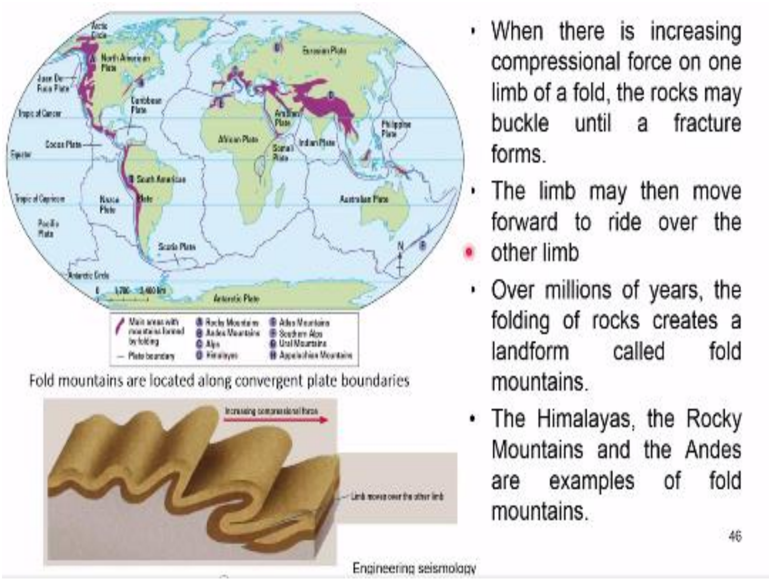

So like that the folding mountain is formed which basically occurs so the actions like this, you can see. So you can see here so this is plate boundary, so the limb moves over other limb because it is pushing. So there is a resistance offered here so there is a pushing happens like this where you can see basically so this is a Eurasian Plate. So it is coming and heating, so this is the Indian Plate when it heating because there is a resistance it tried to fold it like this.

So that is a folding where you can see in the picture you can see this folding. So this kind of folding is not only at Indian Plate boundary, it is also throughout the world several places, you can see here the folding mountain where it occurs. You see these are all the place where the folding take place. So wherever there is a subduction so the continent to continent or continent to oceanic plate heat so there will be folding will take place.

This folding depends upon the location, some of them may be very high, some of them may be very low, but as per this concern, okay the Indian folding is concerned is considerably large amount of the area it covers because of that only if you see the previous slides, the earthquake distribution is widely distributed you can see. So other regions the folding is taking place very narrow band you can see that.

So because of this earthquake in this region are very narrow distribution here a wider distribution. So the increasing in the compression force on one limb of the fold the rocks may buckle until the fracture forms. So it buckles and it breaks that breaking fracture it create a fracture and breaks that breaking also causes a earthquake. So it depends upon the breaking, the size of the earthquake will keep changing.

The limb may be move forward right over the other limb. So over a million of years the folding of rock creates a landform called a fold mountains, so these are all the fold mountains which we have seen here also these are all the fold mountains where you can see that this is a one formation, one formation, one formation. So since this is happening with geological age, so we may not be easily distinguishable.

But if you have the subsequent years of photos continuously like every 5 years, 10 years kind of things from the last 100 years, 200 years or million years then you can see all these variations very well. So the Himalayan as the Rocky Mountains and the Andes are the example of the fold mountains where you can see these are all the some of the examples of the fold. So here the description of the images are given so what it means, what type of fold it is occurring, which place it is all those things.

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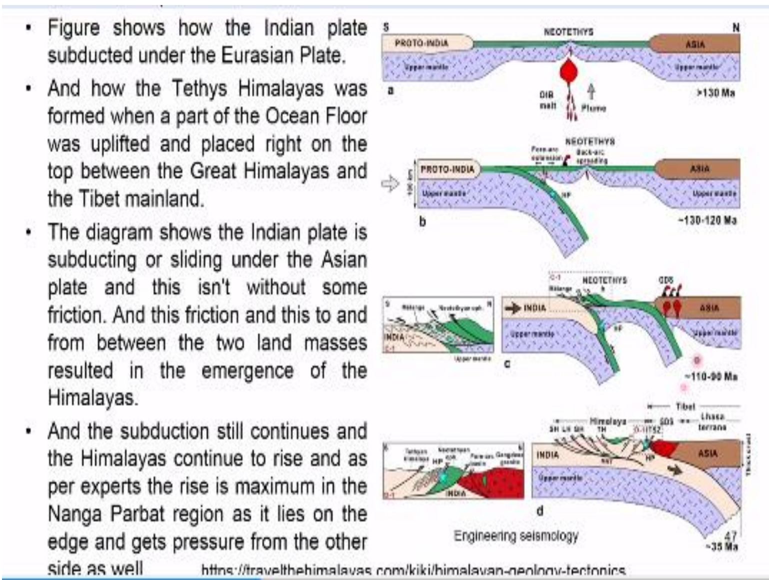

As I told you that in the world there are many beautiful places are created because of the geological action particularly your earthquake and predominantly earthquake and then volcano and landslide those are all the things which create a landform. So let understand how this folding happens in slightly detailed manner. So, this was explained in this particular website actually if you want to get the more information you can go to that website.

So you can see that the Indian Plate subducted under the Eurasian Plate this is actually before the Indian Plate and this is the Eurasian Plate before heating basically the Eurasian Plate are Eurasian Plate. So this is the Indian Plate where you can see this is actually a thinner part of the plate which is moving and when it started like I mean to join together. So because this is having as I told you that the higher density he tried to go inside.

It has a lower density he tried to push inside. So this formation this format basically create a this kind of rupture or folding. So that takes place here you can see here very minute level, they increased like a different part of materials the formation material. So this is how wherever that folding breaks and (()) (11:39) causing a earthquake you can see this. So, this is the today's scenario where there is a high Himalaya, low Himalaya.

Different type of Himalaya so still it keep accumulating and building because this is a geological process it cannot be stopped. So you can understand from all this process that about several million years may be around 30, 40, or 50 million years ago there is no Himalaya. So India was actually around 70 to 60 million years so the India was actually an Island.

So India was a Island there is no mountain. It is a just Island with a plot terrain may be the mountain which is formed due to the ejection of the magma that is what some of the mountain which land mountain where you can seen even in the South India. You can see the individual mountain like hills which is not connected, but just hills that comes due to the ejection of the magma and then that also causes some kind of seismic activity.

This might be there when about 60, 70 years old places there is no big mountain what we are seeing today in Himalaya so that you should remember. So, people how they confirm this, how they take this kind of scenario happened because what I am talking was several million years ago, so how people, so that is they do a detailed geology and the seismotectonics study.

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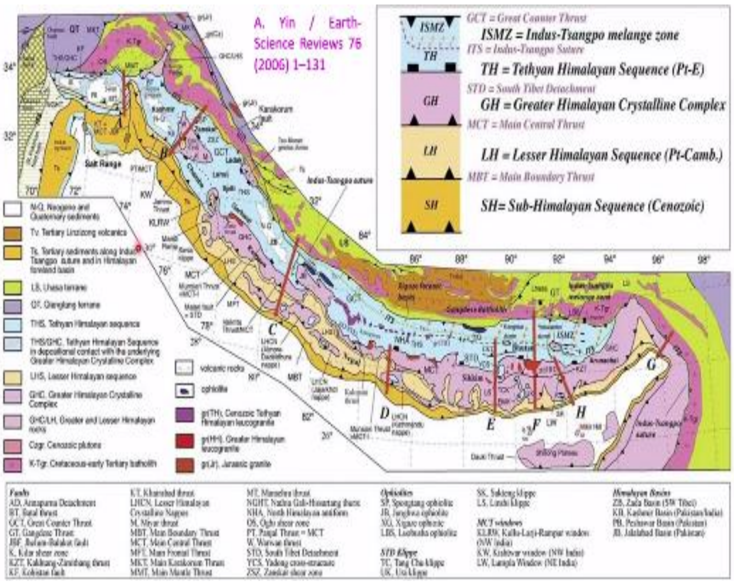

So, what people do basically they go to the landform or the different place. This is actually the entire plate boundary of the North India so covering from the eastern so the eastern part and then the complete northern part and then this is the western part. So people go there and then dig a trench and then do a deep geophysical studies. So, what are the geophysical study, a seismic survey, electric resistivity imaging, and then the ground penetrating radar imaging.

So all those survey they try to see map and where these layering system the change in the material, change in the density will be reflected in this images in the some kind of form and apart from that they also dig a possible way like borehole or cutting a trench and try to collect a sample from that and carbon dated and then they can come to the conclusion that this layer belong into this particular crust, this layer belong to this crust.

This layer is forming and heating and fractured and moved kind of thing. You can see the very nice geological map so this is may be some of I can say that the unique way people can represent a lot of information starting from the place and then the fault type so then the zone, Indus Tsangpo zone, the Great Counter Thrust, South Tibetan Detachment, Main Central Thrust.

So they were given all the information which is very minor level people who are working on seismotectonic they could appreciate this kind of data compilation and preparation of this kind of map. So generally they take a dig trenches and take the data based on the geophysical information they try to relate how it is especially distributed in the particular area and they also given a section on this.

So this particular graph was taken from this place. You can see that it was published on 2006 by compiling from the several authors it is not a one work alone, it is complied from several author where he has given a description about the depth of each layer how it is formed you can see the depth in kilometer, you can see the material type present with a spatial distance. So this is basically the line B, but here actually the lines are given, A, B, C, D, E, and F, H. So this starts from the western part of India and move towards the eastern part.

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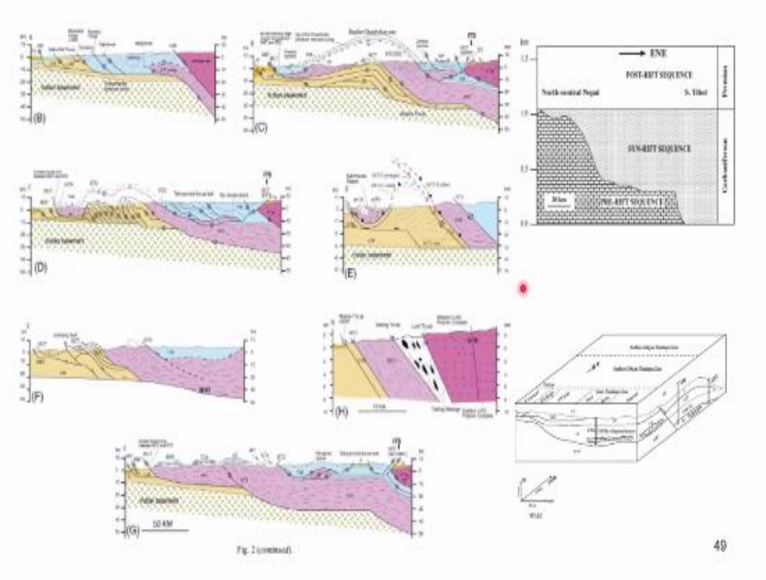

So if you now you can see that how the eastern and western part you can see how basically the sea here how the geology formation changes, you can see the spatial variation as well as the thickness changes. You can see again so here you can see the different material, here you can see, so you can see here, so you can see that basically the complex phenomena, the more and more complex this kind of action the more and more dangerous.

And it says that it is very active. You can see those complex basically when it comes to the F, the H, and G okay the F, H, G so this part actually the complex almost like not so much when compared to the other part. This complex basically explained how the fracturing and folding taking place in this region. So you can also see the north central and then the post dripped.

And the Tibetan plate how the two plate materials as you can see the two materials how this present in the illustrated form like a simple form you can see. So here again if you make that as 3D dimension figure so you can see the place the soil range okay northwest India, Nepal, Bhutan, Arunachal Pradesh. So where you can see the top surface and then bottom you can see a different geological formation of the material.

You can also see the scale of this deposit. So these are all basically they do by even a drilling and taking a sample okay and then carbon dating then cutting a trench and then doing because some of the information you do not get by the cutting because we need a longer depth and then other information like deep level information they get it from the deep seismic geo-profile data or the earthquake recorder data.

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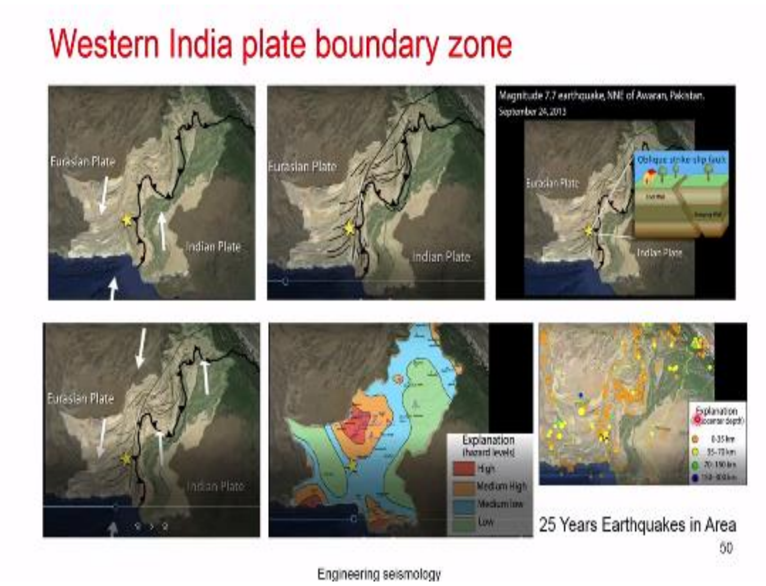

So, let discuss in detail about the so we have seen a northern part how it is exist then goes to the western part of the plate boundary. So this western part plate boundary actually the scientist taken a data from 25 years earthquake in the western part particularly (()) (18:00) of the Pakistan and all those place. You can see this is basically the Eurasian plate and Indian Plate.

So as I told you that the western part having a transformed boundary action that is why you can see here. So this is one of the earthquake so 7.7 earthquake occurred on Pakistan during 2013 September that earthquake reference this description has been made, you can see this is the boundary what we have discussed here transformed boundary. So this is the Eurasian Plate and Indian Plate where you can see the fracturing take place.

You can see the minute level lines as you can see the how the fracturing take place before this boundary happening because both the plates are moving together that particular fracturing you can see the star portion and what happens there you can see how it breaks footwall and then the oblique strike-slip fault pattern so you can see there. So then the action it is happening in the here you can see the force.

The rotational force or the transformed force what happens and how if the earthquake happened there. So with reference to that there seismic zonation map, this is a seismic zone of Pakistan you can see that this particular earthquake was happened where the like high, medium. So the medium low zone similar to India the Pakistan zone map also not may be very accurately where the 7.7 is the big earthquake where this was happened on this place.

Where it has given as a medium low zone in the zonation map. So, you can also see the subsequent location of the hypocentral depth of the earthquake you can see the (()) (19:51) actually happens around 30 to 70 kilometer. So the red one was 35 kilometer less and then the green one were the 70 to 150 and then the other one so the other color very darker one color was actually 150, 300 dark blue.

You can see that this entire location the predominantly the earthquakes are less than 35 kilometer and some earthquakes are 35 to 70 kilometers. So what type of magnitude experience here on this earthquake size and this earthquake size that knowledge will help to predict a better hazard due to this action in the western part of India. This is actually the western part of India where if you want to predict very accurately this kind of information or knowledge are very important.

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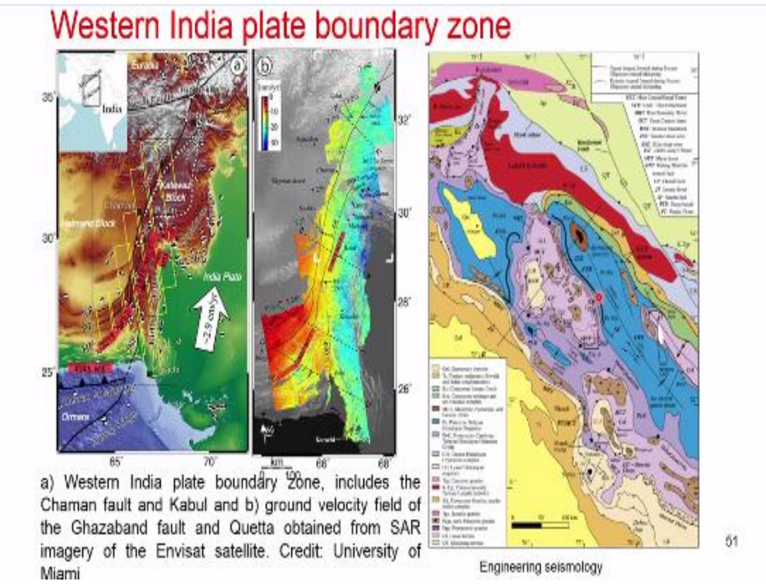

So this is about the western part. So again we can go through in detail another paper where they talk about the this is the place where the India, Pakistan, Afghanistan as discussed. You can see here so the different segment under respective magnitude. So there was a 2013 7.7 magnitude and 1935 7.7 magnitude. There was earthquake in 1931 7.3 magnitude and 1909 7.1 magnitude and then the 1945 M8 magnitude.

So there are different segment you can see the different segment like we have discussed last time last class about the seismic gap a different segment how it rupturing so these areas are. So the place attached to this region particularly the Gujarat and then this other part of India whatever regions there are so somebody has to really concerned about this kind of activity there.

So here the mm per year how it moves so how it moves the information you can guess. So the Western Plate boundary zone includes the Chaman fault and Kabul and ground velocity field so the Ghazaband fault and (()) (21:55) obtained from the SAR imagery. So this is basically from the University of Miami where they published this information. So this place again a detailed geological information, geotectonic so seismotectonic information you can see how the materials geologically it varies with respect to different mineral composition.

So different type of material you can see how complex. So the more and more the complex your sub-subsurface or region and the more and more the tectonic activity taking place are taken place so that we have to remember. So this is about the western plate boundary zone, so what we are discussing that.

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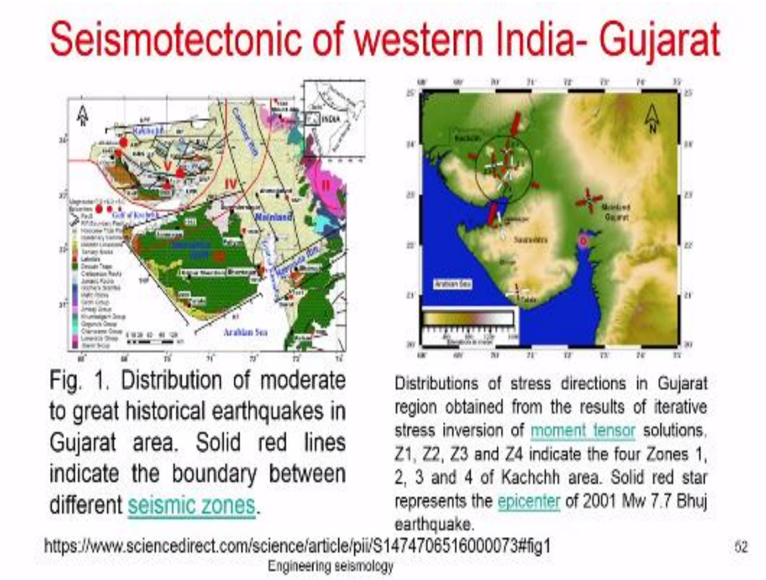

So further the western India so where we concentrated on the little down from the previous discussion where the Bhuj, Gujarat there was a devastating earthquake in the 1891 and then followed by 2001 earthquake where you can see the geological formation. You can see this is the place where the both earthquake are Kachchh region. You can see geologically I mean the seismotectonically how this area is more and more complex.

So this is the Kachchh region there are different zone because of the resistant seismic activity taking place there. So even though this region basically slightly away from the plate boundary because this you cannot call it as a interplate earthquake because interplate earthquake is earthquake which is occurring exactly on the plate boundary a 10 kilometer both side of the plate boundary.

So this happens several kilometers away from the plate boundary. So it is an intraplate nature, but still because it happens due to that previous slide what we discussed the action described here you can see there. So this is the one. So this you can see the activity okay the force happens due to this plate boundary affect and then it happens little far away from the plate boundary what type of action it happens.

So the elevations level and then the earthquake basically the red one basically the earthquake. So the distribution of moderate great historical earthquake in the Gujarat region is actually shown here you can see the dot very dark red color about 7 there are two dot the Kachchh and this one right the Allah Bund, so the dam of God is created on this Kachchh earthquake. Okay, so then followed by the other earthquake 6 magnitude and then 5 magnitude.

And then the other earthquakes you can see. So, similarly you can also see the 2001 earthquake so how the zones are distributed after the earthquake people kept a seismic record, try to record the earthquake data and then get that information of this forces, how the forces are moving using the recorded earthquake data which is essential.

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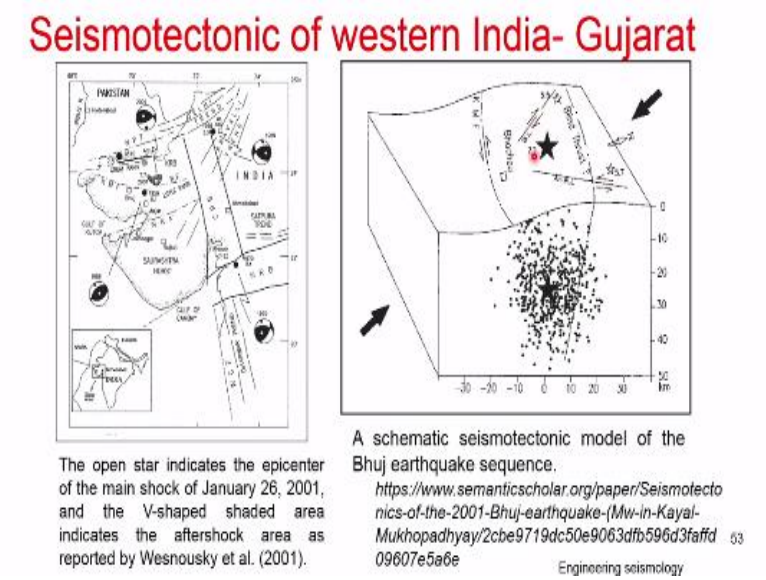

So you can still glance through another papers where which was published after the Bhuj earthquake where people are given a beach ball you can see 1956 what was the force. So this is one, this is actually indicates a V-shaped area aftershock area reported by the Wesnousky. So where he kept the measurement and tried and then he has given the also beach ball here you can see the beach ball.

You can see there is a complex fault and fold present in this region that is why you get the relatively a bigger earthquake when compared to rest of the peninsular Indian part. This is another beach ball so the source mechanism. So the overall you can see that the earthquakes in this region close to 0 to about a maximum of 40 kilometer and how these are folding. So you can see that the fault how it moving on both the direction, how it moves.

You can see that there is a complex geological force acting on this region because of the movement of intraplate, the Indian Plate movement and heating of Eurasian Plate and this complex geological local scenario create a bigger earthquake in this region. So this is one.

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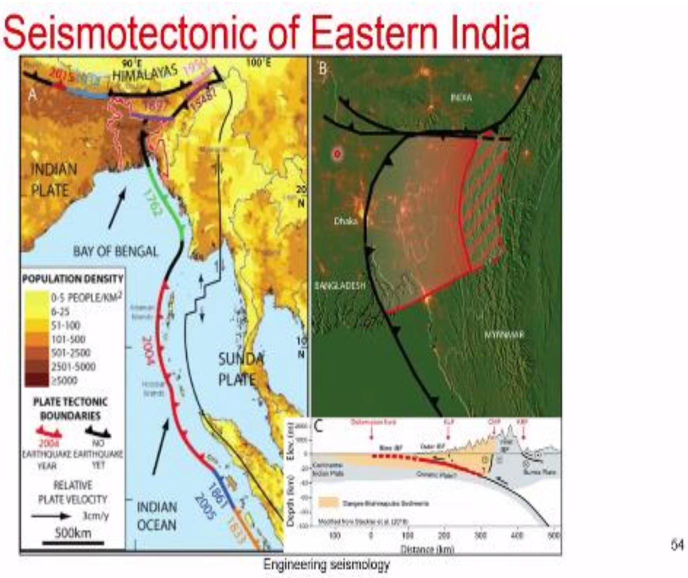

Then next go to the Eastern part of India. So eastern part so this is the segment where you can see the map shows a population density so where the darker color more and more people live very light yellow color where 0.5 people per kilometer square they live. This is basically your northeast, seven sisters, so all the states includes here includes here including the Bangladesh where the highest.

So, you can see that the earthquakes which caused the 2004 tsunami earthquake, this is Sumatra one where you can see a very long stretched breakage which released a huge amount of the energy, so particularly on this place as per the Indian Australian and then Eurasian Plate this will be the highest magnitude ever reported then they subsequently the other places where there is no earthquakes are happening, what is the earthquake duration happen.

So these are all the places where indicate that there may be a possibility of future similar kind of breakage and earthquakes, but as I told you that it is very difficult to predict the earthquake, but still it is better to be, be prepared to face this kind of earthquakes. You can see the cross-section of the eastern boundary how the thickness and Himalayan belt varies and all. So, how the fault two joins it takes into the plate.

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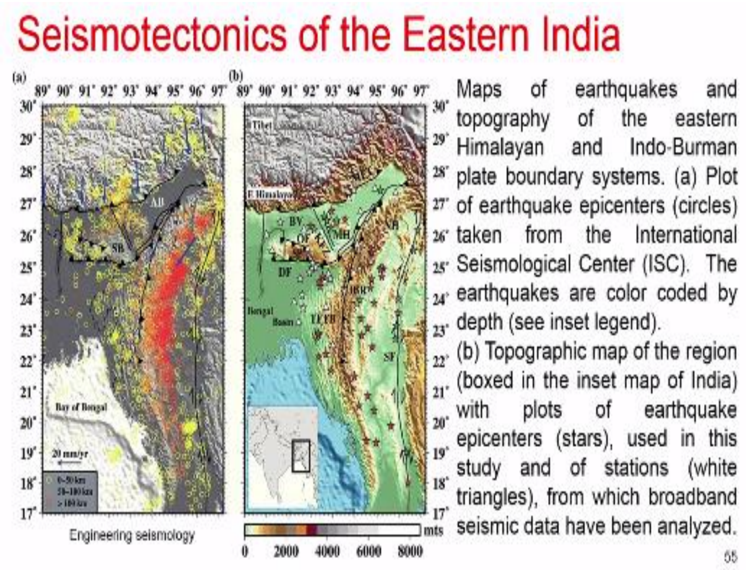

So we can also see the seismic activity. So this map basically shows a topography level okay where you can see the depth of the earthquake you can see and then this is basically the topography in the meter elevation where you can start from the zero where is the main sea level then start slowly going up and up and then it goes up to 6000 and above kilometer on this Tibetan part eastern Himalayan.

You can also see the earthquake here as I told you that in the eastern part of Himalaya more and more complex and the earthquakes are having the more and more deeper than the north part of the Himalaya, you can see here. So the topography of the plot earthquake epicenter is taken from the International Seismology Center, the earthquakes are color coded by the depth see the legend there, topography of the map boxes inset where this topography is mapped here.

So the star used to the epicenters of the earthquakes are basically the stars symbol used. So white triangle for which the broadband seismic sessions are taken. So there was a seismic network installed in that place as I told you the northeast so seismic network when you have discussed the Indian seismic data instrumentation. So those data actually used to interpret and understand what happens in this region that is how the seismic data are useful.

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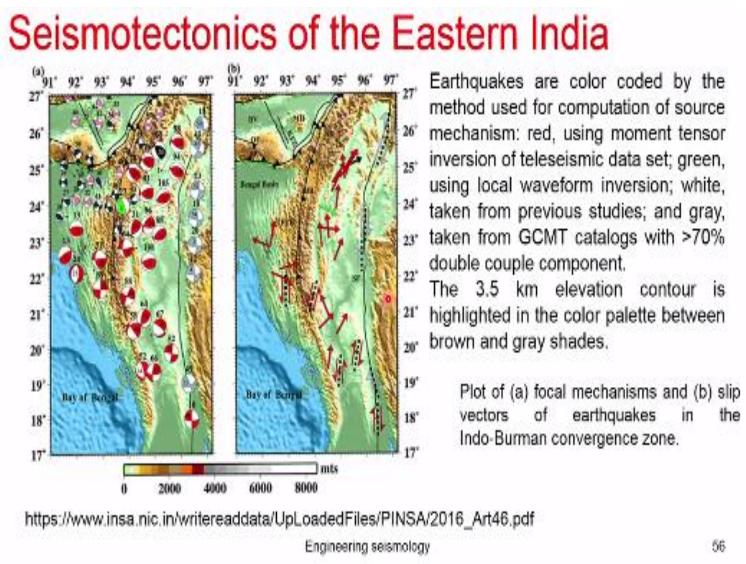

So this is again the eastern part of data, so where you can see that the source mechanism from the different earthquake starting from a small, moderate, big earthquake you can see the source mechanism and a beach ball a respective beach ball. So the earthquakes are color coded by method used to computational source mechanism. So they used a different method of source mechanism, red using the moment tensor inversion teleseismic dataset.

Green using the local waveform inversion, so white taken from the previous studies and gray from the GCMT catalogue which is 70% double couple component. So different method what they use were given. So 3.5 elevation contour highlighted so the color palette between the brown and gray portion of the plate boundary they also given a force, a compressor tensor and then the shear whatever happens at each segment which was recorded data derived information you can see, so those information also they are given.

So these are all the information will help you to get, to decide what is the magnitude I need to take in that region, what is the depth I need to take in this region, what kind of source mechanism I can take from this region. So all those information can be obtained from this kind of data or previous studies. So even though this is not done by the engineers, it is done by the geologist and seismologist, but this data is based for any seismic hazard analysis. So one has to consider this as a basic information to decide how this data are basically.

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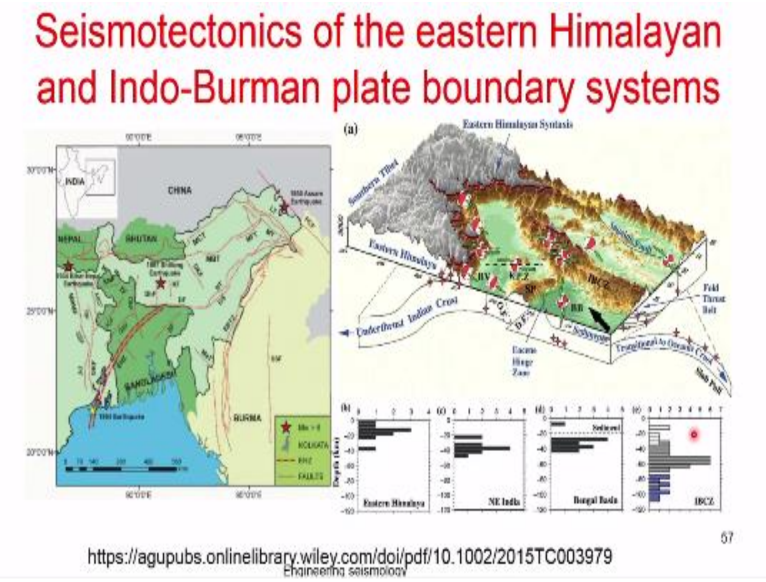

So further so we can also see how the earthquakes are especially distributed in this field, you can see basically the seismotectonic of the eastern Himalaya and Indo-Burma plate, you can see how the elevation, how the earthquakes are occurring at different fault underneath Indian crust, the traditional oceanic crust fold thrush, you can see that the southern Tibet and Eastern Himalayan syntaxis.

Okay, so the different fault whatever previously mentioned KFJ fault all those things we can see the depth of earthquake, you can see the eastern Himalaya what is earthquake, northeast Himalaya what is earthquake, Bengal basin what is earthquake, IBZ what is earthquake. So this depth will give you what type of depth and hypocentral distance you should consider in the hazard analysis.

So we will continue this discussion in the next class. So we have been discussing about the seismotectonics of India, we have discussed about the northern part completely, northwest part completely, we are now discussing the eastern part. So this is how you can see the depth of information, fault type occurred on that places of geological formation in that region using the teleseismic event, recorded earthquake event, deep geophysical survey or any other geophysical survey and trenching.

These are all the data they used to get this information. So thank you very much for watching this video. We will continue our discussion in the next class on the seismotectonics of Indian region again. Thank you.