Introduction to Engineering Seismology

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Lecture – 53
Seismicity of India: Some Past Earthquakes Reported in India – 2

So vanakkam. So we will continue our lecture on Engineering Seismology. So we have been discussing about the; so the different; the tectonic setting, a major okay, the major 3 category so we have discussed so with respect to the past earthquake and how the sequence of the earthquakes are happening and so we have been talking about that. So now we discuss a individual earthquakes, some of the selected.

I am not going to discuss everything, but if you want to see the history of the past major earthquakes actually you can go through this book, so which is the one of the classical book in the history of Indian seismology because most of the books if we see even Earthquake Geotechnical Engineering or other major books which generally referred from the Western countries, okay, where you can see very little information gone into the book with respect to our country, okay so which is very important particularly as seismology point of view.

So this was the book written by scientist, Sir Rao, okay so where the; his name is actually Ramalingeswara Rao so; he was actually extensively worked in the NGRI on seismology. He published several papers, okay, even some of our discussion we might have quoted Rao et al, okay. So the; actually he did seismic activity on Indian scenario so where he has given a broader, okay and as well as in detail, in-depth okay information about several earthquakes in India, isoseismal map and source activity.

So whatever studies are done as on this book published is compiled. It is one of the valuable book, those who want to know more about a local seismic activity in the region, okay they can refer this book okay, so where he also used to call me and discuss about this book. He has supplied this book actually free of cost for the teaching purpose where I used to take many of the notes as well as the reference from this book.

So what we are going to discuss is some of the earthquakes already printed on this book. You people also can buy this book if you are planning to work further on seismic city related areas. So, as we told that the individual earthquakes play a major role in deciding several things, so which we will be discussing in that.

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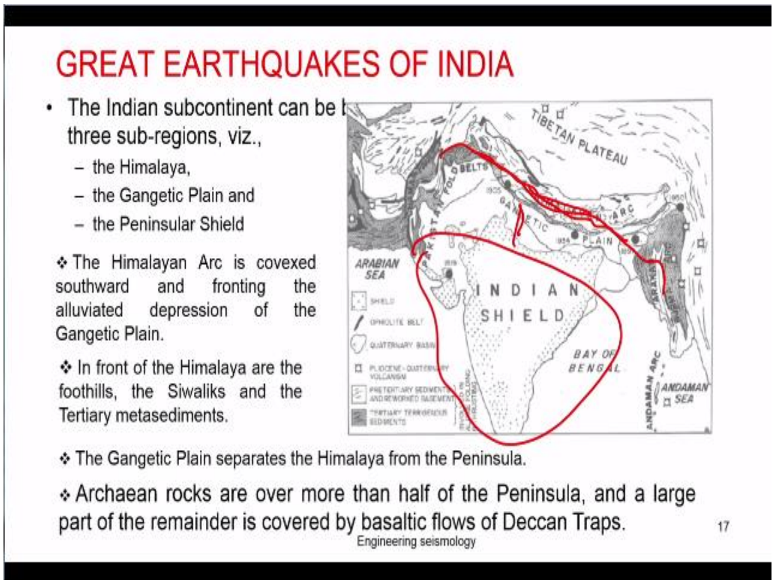

So first let us talk about the great earthquakes in India. So the; as we have seen that entire Indian subcontinent has been divided as a three major categories, so the Himalayan and the Gangetic Plain and the Peninsular Shield, okay so this is what you can see. So this basically the entire thing has been called as Himalayan, okay. So then this is basically called as peninsular India, okay so the in between part, okay, this is the Gangetic plain, okay.

So the Himalayan Arc convexed okay southward and fronting of the alleviated depression of the Ganga plain. So basically this geological wave formation okay and erosion all causes a Gangetic base in soil, okay, so Ganga plain is (()) (03:33); so in front of Himalaya are foothills, okay, Siwaliks and then the territory metasediments, those are all some of the features of the Himalayan belt. The Ganga plain separates the Himalaya from the peninsular India.

So basically the peninsular India more or less the rock, okay, is where you can find very hard rock, okay, at shallow depth, shallow depth means maybe about 100 meters, okay within 100 meters or about 100 meter. So then the Himalayan belt also you will have similar to that rock in the most of the places in the shallow depth, but in between this Ganga plain you have a your rock at a very deep level starting from 100 meter is the minimum depth and then it goes up to 6 kilometer where the is rock; so that means so much of thick soil deposit found in the Gangetic plane, okay, so that is one of reason.

So the Archean okay rocks are over more than half in the peninsular India. Large part of remainder covered by the basaltic flows up Deccan trap, okay so these are some of the geological this one where you can see the distribution of the geological formation and then the valleys and basins, okay, all the larger geology map, okay.

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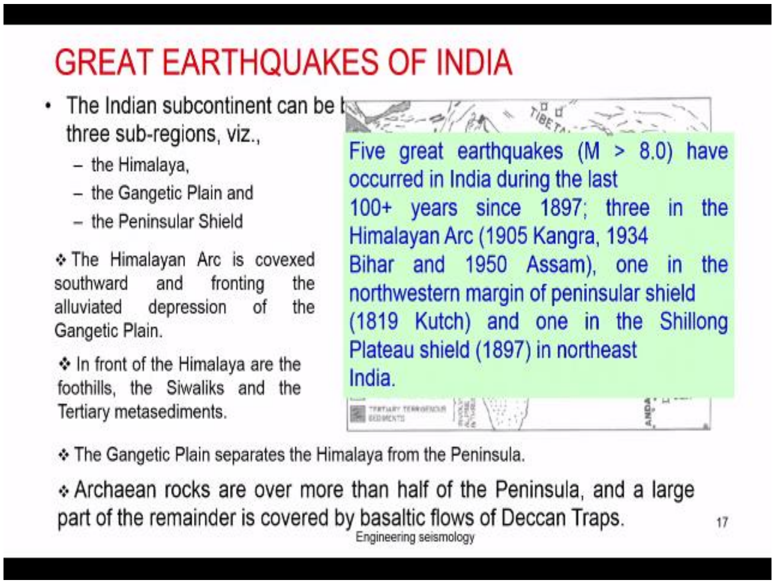

So 5 great earthquakes, okay we are talking about the great earthquakes. So great earth means earthquake magnitude above 8, okay the earthquake magnitude elbow 8 is called as a great earthquake. So about 5 great earthquakes have occurred, okay in India. So five great earthquakes; most of them have occurred in the belt, okay, so the Himalayan belt. So this was actually in the 100; around like last 100+ years, since 1897, okay.

So there are three in Himalayan Arc like Kangra, Bihar and Assam; one in northwestern peninsular shield, the Kutch one also which is very close to 8 magnitude or the oldest one claimed to be 8 and the above and one Shillong plateau in 1897. So these are all the earthquakes having 8 and above magnitude which are called as great earthquakes of India.

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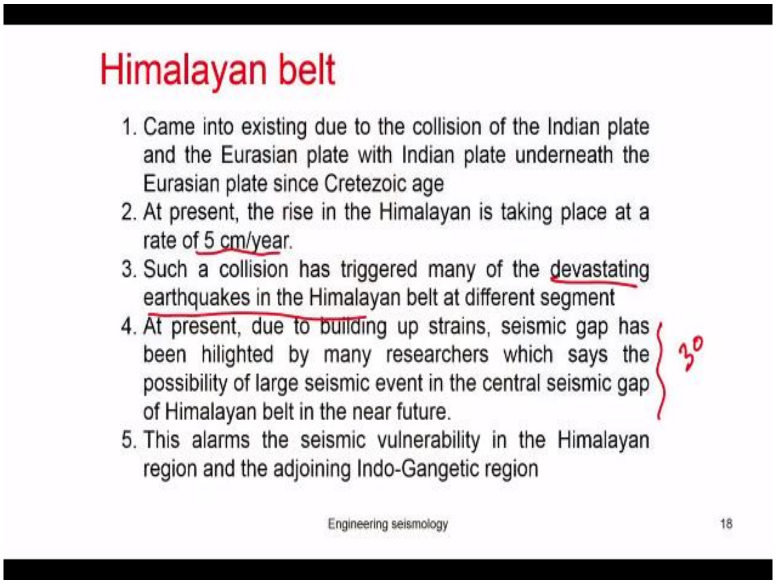

So the Himalayan belt come into existence due to the collision of Indian plate and the Eurasian plate with Indian plate underneath a Eurasian plate since the Cretezoic age, the rock formation age. At present, the rise of Himalayan is taking place at the rate of 5 centimeter per year, which is the rate of where the plate is moving, our plate is moving (()) (06:16) speed, similarly the rise of Himalayan also happens.

Such a collision has triggered many devastating okay earthquakes in Himalayan belt and a different segment. At present, due to building up strain, seismic gap has been highlighted by many researchers which says that the possibility of large seismic event in the central seismic gap of Himalayan belt in the near future. So this seismic gap concept exists since last 30 years, okay. The Bilham is one of the scientists who claimed that the seismic gap can explode anything, but fortunately until now, we have not experienced any great earthquake.

So that is a one thing we should thanks to the God, but I do not know how long it will continue. As I say that, the strain building up, okay, is the one of the major cause of earthquake. So the stain has to be released at one point of time. It may happen in the lifetime of our period or your generation or your next generation, we do not know, okay. But the building up of strain always causing a earthquake, okay, which is really significant in the Himalayan belt as there are many earthquakes are occurred 500 years, 300 years, 700 years before, not a recent past, okay.

This alarms a seismic vulnerability of the Himalayan region adjoining the Indo-Gangetic Basin. The peculiar thing is that any earthquakes on the plate boundary, okay, since the highly populated urban settlements are on the Gangetic plain, so any earthquakes occurring on the plate boundary also affect a Gangetic plain settlement, okay. So starting from the Uttarakhand and Haryana, UP, Bihar, okay, so this side West Bengal, okay, then the Bangladesh and then even further like part of the Orissa so these are all the places where one can expect a; this kind of devastation due to any big earthquake in the seismic gap, okay.

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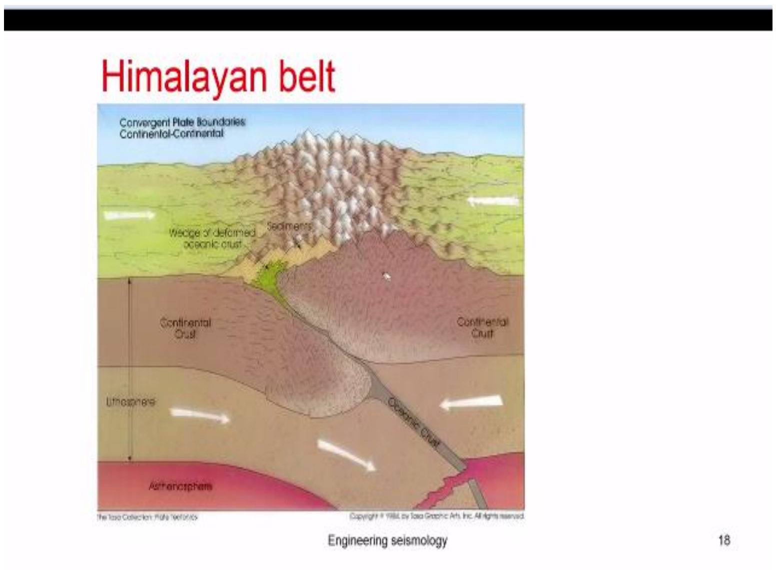

So this seismic gap occurs because of your Himalayan action, okay, were the two crusts hit each other. Okay, so we can see that this is actually the continental crust, okay this is again the continent crust. So this hitting each other, there is a; oceanic crust, so in between it has sandwiched this. So this lithosphere moment hitting up both actually as we are seeing that this was once moving at the speed of 20 centimeters per year.

So now because it hit the Eurasian plate, the speed has been reduced to 5 centimeters per year. So both are hitting basically, the hitting form a many hills okay so these hills basically; below these hills, there are many segment and facture, okay, a fault zones exist which will keep releasing the energies whenever it is exceeding its capacity.

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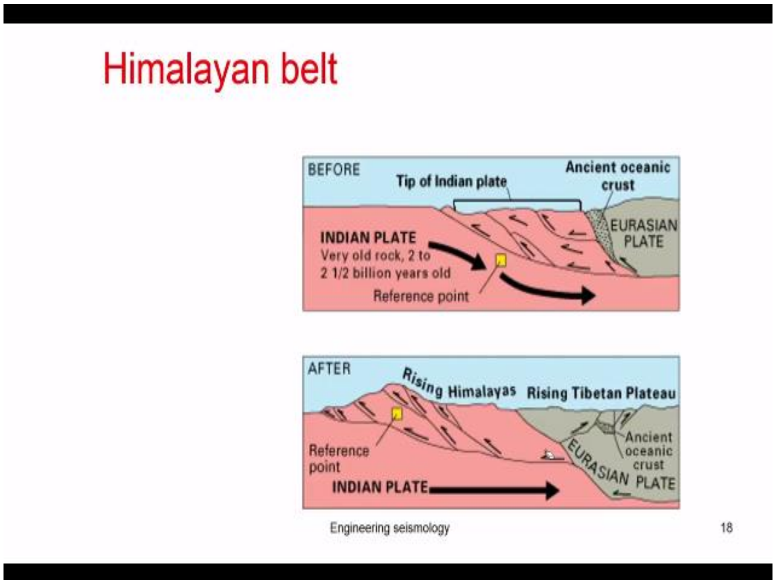

So this is before forming the Himalayan Hill, so this is the Indian plate as we have seen that this is a; like very old rock, so where the carbon dating the rock indicated that, that particular place where 2.5 million years old rock was there then followed by this is the Eurasian plate where the ancient oceanic crust is there. So this is actually the tip of Indian plate at the time of like both of them are hitting, okay, about 2.5 million years ago.

So then after that it slowly starts pushing each other and then because of this hit, there is a lot of disturbance, okay, in the geological formation and tectonic activity. So this point now here from here it is moving like this, you can see, okay. So there is a lot of fracture and then the formation and then joints, okay. So these are all moves in the age of geological period, okay, which you cannot physically see yourself what happens, okay.

But in the longer run okay; 5 centimeter per year, so if you see your career of like 50 years, so you can see only 250 centimeter growth or variation, that is what people keep noting down, and with evidence of accumulation of large amount of this kind of data, people proved that this action is taking place here which is necessary to be considered for any future seismic hazard assessment.

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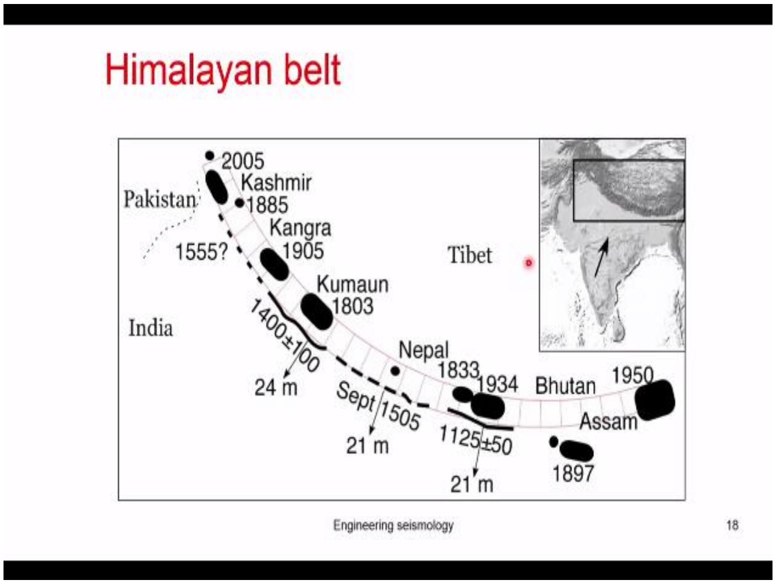

So this are some of the classical earthquakes and their strain level released, the amount of strain released. So there was about 2005 earthquake we talked; so then the Kashmir 1985, the Kangra earthquake and then Kumaun earthquake and Nepal and then this is again the; there was some old earthquake so 1833, the Bhutan, the Assam earthquake. So this indicates a more or less a; your magnitude of earthquakes, okay. The bigger in size means a greater earthquakes or larger earthquakes are occurred.

Smaller means, it is a smaller earthquakes are occurred. So there are segments, okay, so where you can see these are all the segment there the movement, the slip is taking place so much but it has not released that energy, the movement is taking place but not released. So those are all the places where this is actually called as a Western seismic gap, this is the Central seismic gap, this is the Eastern seismic gap.

People believe that these places there may be chances of bigger or greater earthquakes in the future. So that future again I told you that it is very difficult to precisely tell what is the future. So as I told you that this seismic gap concept has been introduced and discussion in the last 20-30 years, okay but so far as of now nothing has happened. Somewhere we should be happy about that, okay, but same time, it may happen anytime, okay, which may happen during our lifetime or next generation or next generation as these earthquakes are having very large return period, okay, 500 years, 300 years.

Precisely pinpointing when it will happen will be very, very difficult, okay. So it is a better ways to prepare ourselves by understanding the; this earthquake what happens on this earthquakes how it damage, how much extent it damage?

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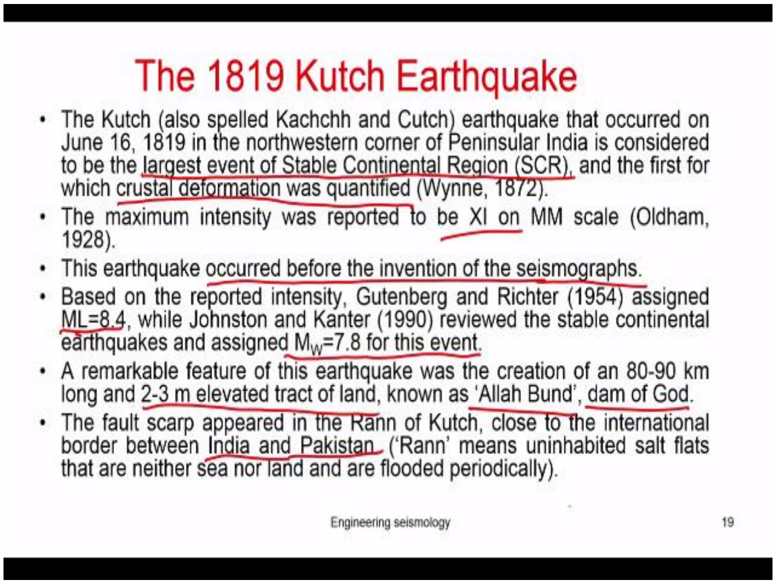

So one of the classical examples, the great earthquake which we start was actually the Kutch earthquake. The Kutch earthquake was occurred in 1819, okay. It is called as a Rann Kutch or Kutch, so that occurred on June 16th in the 1819, northwestern corner of peninsular India, considered to be the largest event in the peninsular India. So this is the largest peninsular earthquake, okay, so in the world.

The first for which the crustal deformation is; was quantified. This is also a crustal deformation was quantified by doing a detailed study and modeling. The maximum intensity reported on this was actually XI on Modified Mercalli intensity scale where reported by Oldham actually based on some report and other things and all. This earthquake occurred before the invention of the seismographs.

You can see. So that means there is no way you can get a seismic record of this earthquake, okay. So based on the reported intensity, the Gutenberg and Richter okay assigned a magnitude of 4.5. This is basically paleoseismology study people have reported. Here you can also note that

8.4 is not a valid Richter magnitude. So I hope you are all aware. Up to 7 only it is valid, beyond 7 it saturates, but still the literature people like reported those things based on the; I mean the some kind of paleoseismology studies understanding.

The review was stable continental earthquake and assigned, okay, magnitude of 7.4; 7.8 for this event. So because of this 7.8 and 8.4 still it is ambiguity what was the magnitude, but since it caused extensive damage and intensity of 11 and above, so this can be called as a great earthquake. A remarkable feature of this event was creation of the 80-90 kilometer long and 2-3 meter elevated track land which was, I told you that, known as Allah Bund or a dam of god, okay. So there was a projection above the surface, okay.

So such kind of projection was created with length of 80 to 90 kilometer long with 2 to 3 kilometer height, okay, so in between basically Pakistan, okay. Actually the fault scrap appeared Rann of Kutch close to the international border between the India and Pakistan, okay. So Rann means the; uninhabited salt flat that are neither sea nor land and are flooded frequently. So that is a Rann. So this is called a Allah Bund or dam of God where it is projected above ground 2-3 meter like some kind of elevation created in the so long which was naturally created.

Still this exists. So if you have a chance or if you are from that region, you can go and see how it exists. As I told you that many of the beauty in the world occurs due to the earthquake, okay. So a deep valley or nice hill or slope and river, all those things basically geological formation, this geological formation happens by landslide and earthquake. So basically the earthquake is one of the; the event which has basically carved the world into the beautiful shape and terrain, okay.

So, the XI what intercity says, the total damage, okay, few if any structures standing, bridges destroyed, wide cracks in the ground, waves seen on the ground. This is the description given for the intensity XI.

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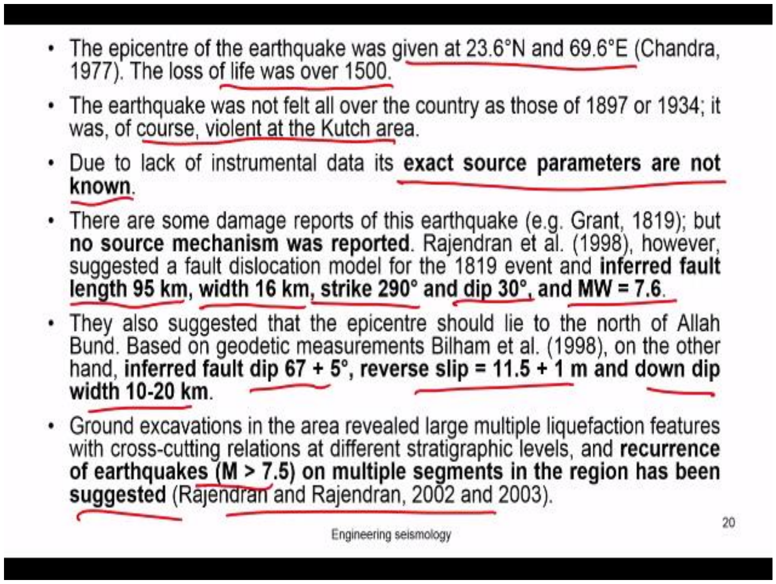

So the epicenter of earthquake was given, this is the estimation based on the paleoseismology, okay, Chandra 1977. The loss of life was about 1500, I mean they estimated and it was reported in the past they have taken. The earthquake was not felt all over the country, those 1887 or 1834 it was of course violent in the Kutch regions, okay. So this was the observation of the literature. Due to lack of instrumental data, exact source parameters are not known for this earthquake.

So there are some damages reported in this earthquake, okay. The Grant 1891 report is there; no source mechanism was reported. However, the fault dislocation model 19; 1819 event and inferred that fault length will be roughly 95 kilometer, width will be 16, strike will be 290 degree, dip will be 30 and MW will be 7. These were some of the model studies based on the data collected and they tried to get this information.

They also suggested that epicenter should lie to the north Allah Bund based on the geodetic measurement of Bilham 1998. So other hand, the inferred fault dip so much, reverse slip and then down dip so much, okay. So there is a; some slight difference but these are all based on some kind of estimation and assumption. So there may be always the right and wrong things can be discussed in the desk, okay. But overall, this information is arrived by modeling.

That is the message you can get because when we are talking about the seismological modeling aspect, particularly synthetic ground motion, simulation of synthetic ground motion, we have been talking about the importance of the source parameters, so those are all the parameters based on the similarities it has been arrived. The ground excavation in several areas reveals large multiple liquefaction features of cross-cutting relations at different stratigraphic levels, recurrence of magnitude of 7.5 and above, multiple segments of region has been suggested.

So there is Rajendran and Rajendran, Kusala Rajendran was I keep telling, paeloseimology study they do, so those people basically have done this kind of excavation, and based on the liquefaction features they reported that this maybe a kind of magnitude one can expect on the under that level where there are no such measurements available.

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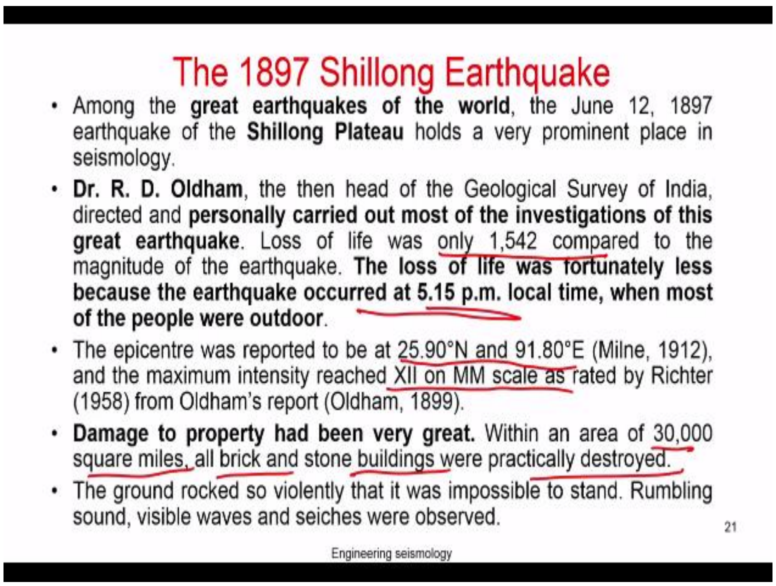

So, another great earthquake is Shillong earthquake. The Shillong earthquake was the great earthquake of the world. So, June 12, 1897, earthquake of Shillong Plateau holds a very predominant place in the seismology because this was the one of the oldest well-documented earthquake. So, Dr. D. R. Oldham, when we were discussing about the seismic instrumentation, we told about this Oldham studies and all.

So the head of Geological Survey of India directed personally okay, director and personally carried out most of the investigation of this great earthquake, loss of life, okay about 1542 people compared to the magnitude of earthquake. So, so many people have died actually, okay. The loss of life was fortunately less because the earthquake occurred on evening time, you can see. So, generally evening time in India traditionally people sit outside the house not inside the house, okay.

So even those who are living in the villages and all, those days there is no power, so generally what happens when sunsets, people will come back to home before sun setting and then try to finish a dinner before sunset completely goes off. So because of that evening time generally people used to play outside and sit outside the home, make cooking or discuss something, something, so that was a favorable reason where less number of people died, okay.

As I was telling you that the time of earthquake also plays a role in deciding the devastation of the particular earthquake. The epicenter was reported to be so much based on the field observation, okay, and the maximum intensity XII on MM scale and this one, the Oldham report also says. Damaged property had been very great. Within an area about 30,000 square miles, okay, all the brick, stone buildings were practically destroyed.

You can see that 30,000 square miles area has been affected, okay, such a very big, large extent area which used to be noted, which is very important, okay when we are talking about the selection of seismic study area, these information are useful, that is why I am discussing the detail about this earthquake. The ground rocked violently that was impossible to stand. That means people felt that it is like standing in the running vehicle, rumbling sound, visible waves, and seiches were observed.

Seiches means, the waves, tsunami kind of waves in the lakes close to water body are the seiches which we have discussed, okay. So, the XII says total damage, waves seen on the ground, object thrown up to the air, all the objects in the ground were thrown up to the air, those kind of the definition given for the intensity XII.

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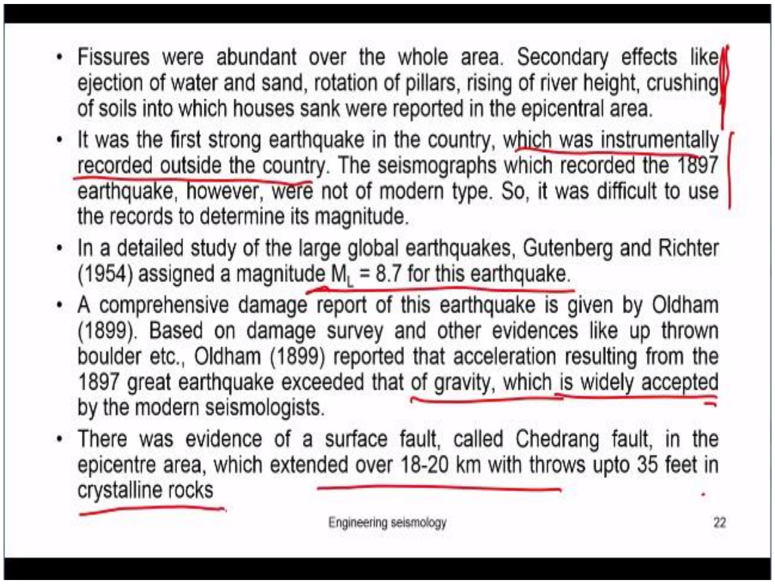

Fissures were abundant over the whole area, which may be due to the liquefaction. Secondary effects like rejection of water and sand, rotation of pillars, rising of river height, crushing of soil which houses sunk were reported in the epicenter. These are basically the liquefaction phenomena, ground deformation phenomena which has been reported and the evidence has been collected.

It was also first strong earthquake in the country which was instrumentally recorded outside the country, where this earthquake was basically recorded some other place in the world. Seismogram which recorded is 1897 earthquake, however, were not modern type, so it was difficult to use record to determine the magnitude. Only the earthquake was recorded but it is not very useful, it is analog seismometer.

As you know that, 1880 only seismometer was developed, those times this was analog in nature. In a detailed study of large global earthquakes, Gutenberg and Richter assigned a magnitude of 8.7 for this. So, the Gutenberg and Richter basically worked out based on this data. This is the assigned magnitude. So, the comprehensive damage report of earthquake given by Oldham based on damage survey, other evidence like up-thrown boulders, Oldham 1899 reported that acceleration resulting from the 1897 great earthquake exceeded the gravity that means more than a G, so widely accepted by the modern seismologists.

So there was evidence that surface fault called Chendrang filed in the epicenter area which extended so much length thrown up to 30 feet crystallic rock, okay. So this is the fault they believed that which is responsible maybe caused the earthquake.

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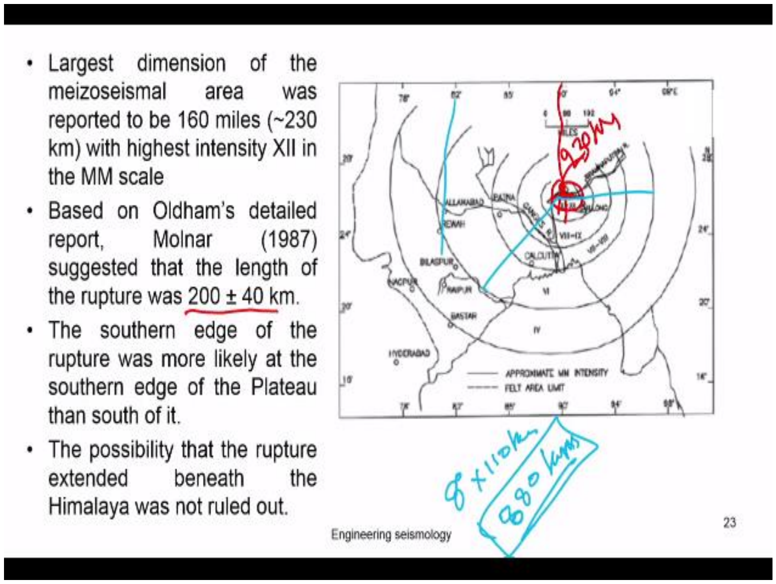

The largest dimension of the meizoseismal area was reported to be 160 miles which is close to 230 kilometer with highest intensity of XII. So, that means, this area, okay the intensity of XII is basically 230 kilometer radius, okay. So based on the Oldham detailed report, Molnar 1987 suggested that the length of rupture maybe around 200 plus or minus 40 kilometer rupture length it was taken place.

The southern edge of rupture was more likely the southern edge of the plateau than south of it, okay. So, the possibility of that rupture extent beneath the Himalayan was not ruled out, okay. These were some of the observations they have done. So as we have seen that, any intensity, 5 and above is always interesting for the engineers, so with that this one, if you see, this is your roughly 90s your epicenter; for example, this is you take as epicenter, okay, then highest radius, see the highest and smallest radius.

So if you roughly take that 82, okay, which is 90 to 82, how many degrees, it is 8 degrees, okay. So, if you take roughly each degree is 110 kilometer, the distance, the degree to this roughly, you can see that about 880 kilometer where the damages are extensive. The intensity of five and six is a concern for them, so, so much area it caused the damage, okay. It is from the evidence from the past earthquake. These information are very useful. We will be discussing this when we need in the future classes.

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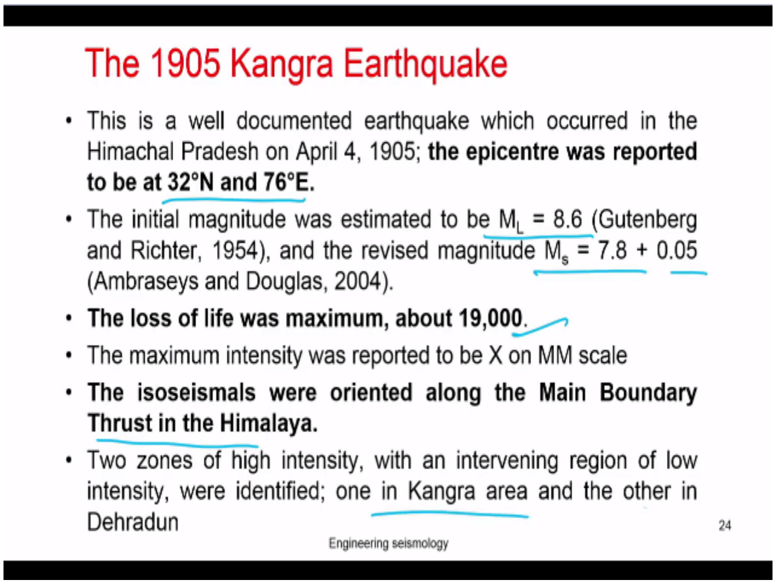

Another earthquake is actually the Kangra earthquake. This is a well-documented earthquake which occurred in Himachal Pradesh on April 4, 1905. The epicenter was reported to be a this location. So initial magnitude estimated ML 8.6 and the revised magnitude of MS 7.8 plus or minus 0.005, so the Ambraseys and Douglas 2004 there; loss of life was maximum, about 19,000 people died.

Maximum intensity reported to be the X on MM scale. Isoseismals were oriented along the main boundary Thrust Himalaya. Two zones of high intensity, with intervening regions of low intensity, were identified, so one in Kangra area and other in Dehradun. So this earthquake basically caused a paleo pattern which is unique in nature, where the higher intensity reported here as well as reported here.

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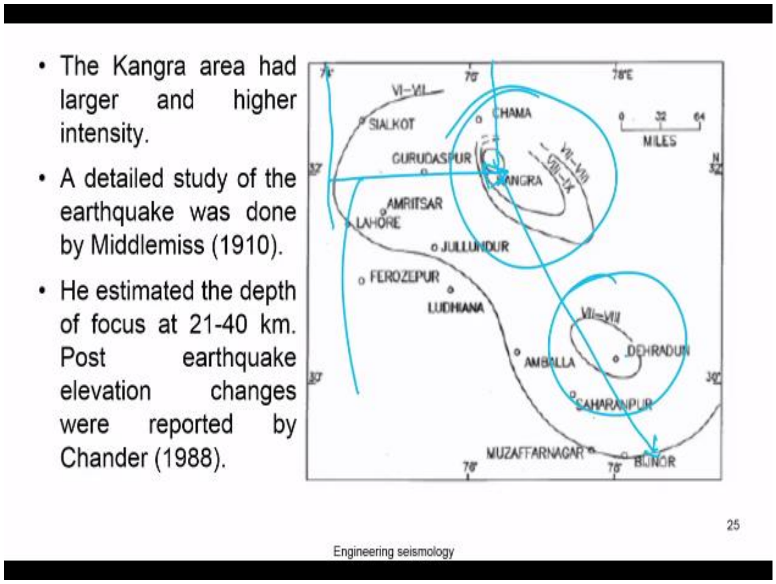

So here also you can see that the six and seven intensity -- for example, you take roughly the 71 maybe the 76 or 78, I think, okay, so you can see this distance. So this will roughly give you a degree conversion and the possible distance damage, okay. So, similarly this distance; so the highest damage one can expect what is the extent expected. So this is another classical example where the soil, the modification of the wave due to the local geology.

You can see the higher intensity here, higher intensity here, where maybe the urban settlement because of that the intensities are higher. People are reported, buildings are damaged, and wave modifications are seen visually, okay. Those are all the things.

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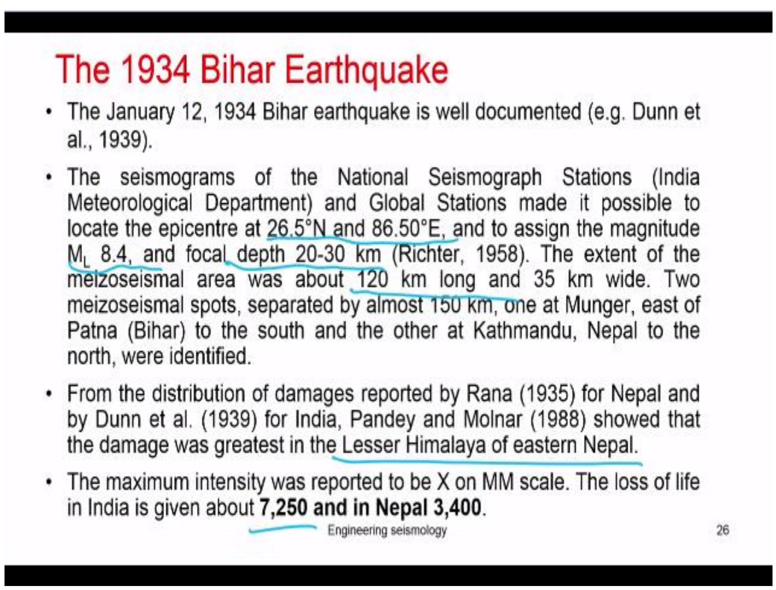

So another earthquake is the Bihar earthquake which happened on 1934, January 12, so well documented by the Dunn, 1939.The seismologists of National Seismograph Station (India Meteorological Department) and Global Seismic Station made possible to locate epicenter more or less accurately to assign a magnitude of again M8.4 and then the focal depth of 20-30 kilometer.

So these information are very important, we will be taking this appropriately when we do the seismic hazard analysis. So, the extent of the meizoseismalarea was about 120 kilometer and 30 kilometer wide. Two meizoseismal spots separated almost 150 kilometer; one at Munger, east of Patna, Bihar to the South and the other at Kathmandu, Nepal, were identified. From the distribution of damage reported by the Rana for Nepal and by Dunn for India, the Pandey and Molnar showed that damage was greatest in the lesser Himalaya of eastern Nepal.

So, these are the places where high damages were reported. Maximum density was reported to be 10, the loss of life was about 7250and in Nepal 3400.So, closely, it is about more than 10,000 people died due to this earthquake.

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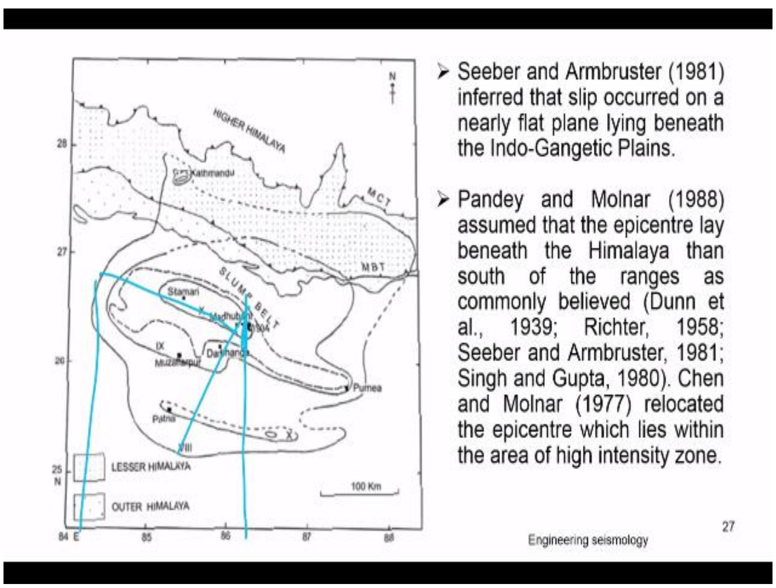

You can see this earthquake and then the damage distribution and then the epicenter location, okay, so there you can see that this is basically a spot, okay. So this is 7 intensity so you can basically define here, this radius, okay. You can see this is almost close to 76, 76.2, so this is around 84.2. You can see like more than like 200-300 kilometer where the damage was extended, okay.

So Seeber and Armbruster, 1981 inferred that slip occurred on a nearly flat plane lying beneath the Indo-Gangetic Basin, okay. So, this was the first earthquake ruling out the source below the Indo-Gangetic basin. So, Pandey and Molnar assumed that epicenter lay beneath the Himalayan than south of ranges as commonly believed, okay. So, then the Chen and Molnar relocated the epicenter which lies within the area of high intensity zone, okay in that Seismic Zonation map.

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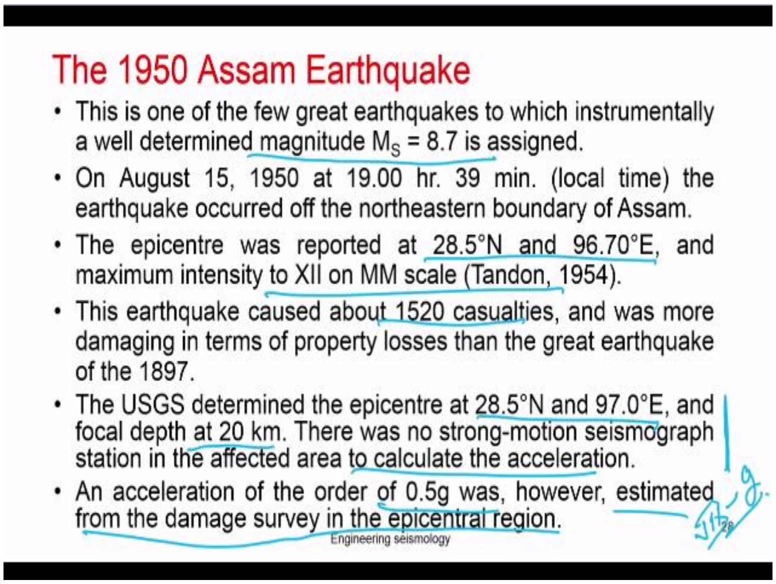

So the another earthquake is at 1950 Assam earthquake. This is one of the few great earthquakes which instrumentally well-determined magnitude of 8.9. You can see the magnitude was reported here basically a surface wave magnitude, MS, okay, you should remember. So now you can recall why we studied all the history of magnitude development, okay, how to assign that magnitude, how to estimate that magnitude.

On August 15 okay so about 7 O'clock okay 7; like like night 7 O'clock 40 minutes local time, the earthquake occurred northeastern boundary of Assam, the epicenter was reported to be a this region and the intensity of XII has been reported by Tandon, okay. So earthquake caused about 1520 casualties, was more damaging than the property losses than the great earthquake of 1897.

So USGS determined the epicenter location of so much, okay, which is more or less similar and the focal depth of 20 kilometer.

There was no strong motion seismogram station affected area to calculate the acceleration. So even though India established station, okay, after Shillong earthquake around 1990s, but still we do not have many stations. We had only 2-3 stations up to 1960s, so that is why these earthquakes are not recorded in India. An acceleration of order of 0.5g was however estimated from the damage survey of the epicenter. So, as you told that if you have the intensity value, you can convert it to g value approximately. There is a relation existent between these two, okay.

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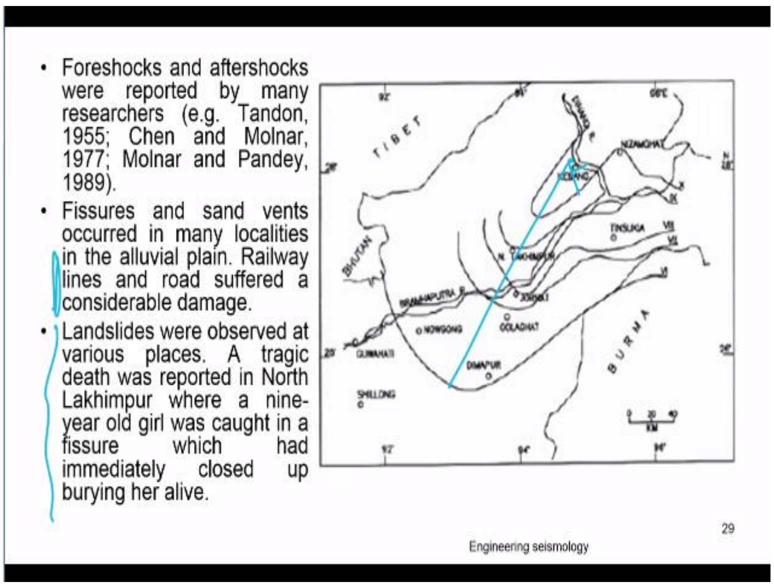

So the foreshock and aftershock was reported by many researchers. Then the fissures and sand vents occurred, the liquefaction was reported. Railway lines and roads suffered the damage. So this was the first earthquake talking about the road damage and railway lane damage in the India. So, you can also see the location and the damage distribution reported. Landslide was observed at various places, tragic death reported North Lakhimpur where the 9-year-old girl was caught in the fissures which had immediately closed up burying her alive.

So, there is evidence that there was the opening up or the fissures or sand boiling, where the people have basically gone inside the sand boiling. It is very tragic accident, that was basically when you have the big liquefaction that has to be this one. So, the seismic hazard analysis or

Zonation of this area needs to account to all these things. They need to consider this as a useful information to estimate a future hazard in this area. Okay, that is one of the need that is why I am discussing this in detail basically.

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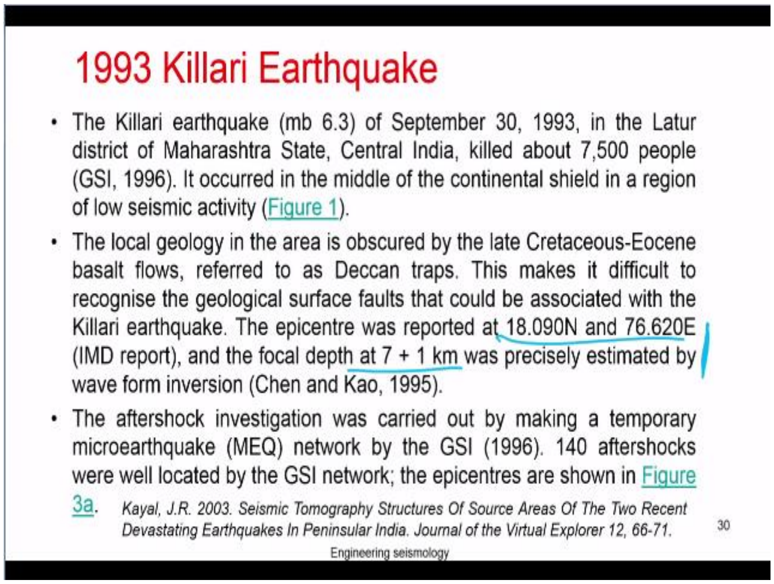

So another earthquake; so there are two earthquakes which we are going to discuss, mostly these earthquakes are in the southern part. One is the Killari earthquake which was mb 6.3 occurred in 1993 September, Latur district of Maharashtra, Central India, killed about 7500 people, occurred in middle continental shield region, low seismic activity. Local geology area observed the late Cretaceous-Eocene basalt flow referred as a Deccan trap.

This makes difficult to recognize geological surface fault associated with the Killari earthquake. The epicenter was reported, this is the one, okay. So then the focal depth of about 8 kilometer. You can see that this earthquake is very shallow compared to the earthquake what we discussed, that is one of the things. The aftershock investigation carried out making a temporary micro-station by the GSI. 140 aftershocks well located by GSI network. Epicenter was shown in the next page we will see. So this information you can get it from this paper which I read and summarized for you.

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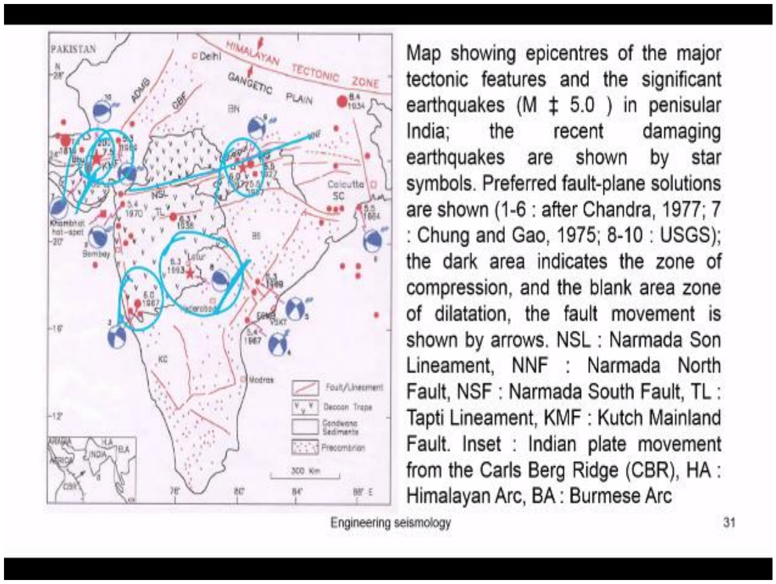

So this is basically the location of the different earthquakes in the peninsular India, okay, where the Latur and then the earthquake what we are discussing basically the Killari, okay, so it is called as also Latur earthquake, you can see this earthquake. So this is the earthquake, this is the beach ball. We were talking about the beach ball no; you can see the beach ball. These are all the different beach balls which is published for the peninsular India.

So maybe this information is also useful when you want to model synthetic ground motion at particular location. Map showing the epicenter of major tectonic and significant earthquake of m plus or minus 6. So, okay, in India, the recent damaging earthquakes shown by star symbols like this earthquake, okay, so this earthquake, so then this earthquake, Jabalpur earthquake; these are all the recent earthquakes after 1950, okay. Some of them are very old. So this is actually again the Koyna earthquake, okay.

So the dark area indicates zone of compression in the beach ball and blank area zone of dilation. Fault movement shown by the arrows, so there is an arrow which shows a fault movement how it moves. You can see the arrow which shows actually, okay, where you can see the fault plane are moving. Also they defend your fault like the Narmada Son Lineament, which is this one basically, okay.

Then the Tapti liniment, then Kutch Mainland Fault, this one, okay. Indian plate movement from the Carls. So, these are all some of the geological evidence and data collected together and prepared this kind of maps, so particularly the Killari earthquake where we have been discussing.

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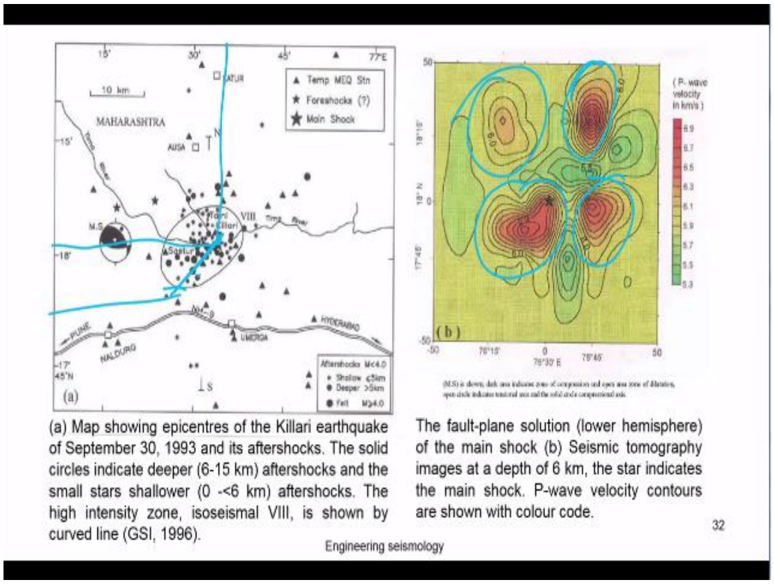

So this is the epicenter map of Killari earthquake. So you can see the epicenter is somewhere here so which is around 30 to 45, 15 degree, so it may be around close to like 40 or 38, okay. So then you can see the intensity of 7, where this is the level, the distance maybe we should take like this okay. So this was basically 18-19 or 16 and then this angle. So if you calculate this, you can see this distance is quite large, okay, when compared to the size of the earthquake.

Map showing the epicenter of Killari earthquake, aftershock on solid circle indicates a deeper 6 km aftershock and small shallower shocks. So the high intensity zone 7 is shown in the curved line. This map was prepared by the GSI. So, the fault-plain solution, lower hemisphere, of the main shock, seismic tomography image depth of6 meter source, there is a difference in the geological materials like rock, you can see, okay. Star indicates the main shock, P-wave shows the contour code, okay. So the P-wave velocity which shows your material stiffness, okay, the compressibility index kind of things which can be easily.

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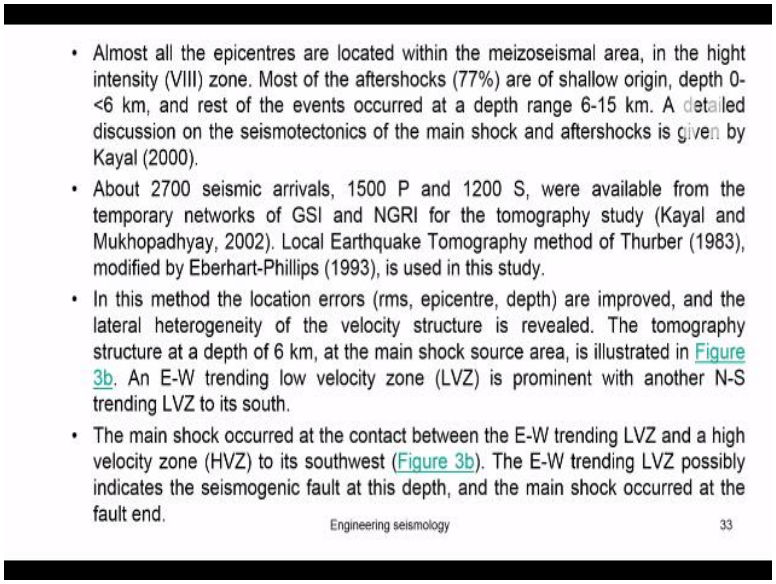

So almost all the epicenter are located within the meizoseismalarea, so the intensity is 8, most of the aftershocks 77% are of the shallow region. Depth was around 6and 6-15 kilometers.2000 seismic arrivals collected, the P wave and the S wave they are taken and they tried to understand the source nature, okay, dialyze and contraction, getting up source parameters. All those things they tried to understand using the aftershock data, okay, which was one of the classical information people have done, basically the GSI then the NGRI.

They have done extensive studies on these earthquakes and reported. Even you know that the seismic code was revised after these earthquakes, okay, where it was elevated from zero to higher level zones. Okay, that was the this one. So this is about the individual earthquakes, it is damage distribution which will be useful to understand further seismic hazard estimation related studies. Collect a data for that. So with this, we will close this class.

So, thank you very much for watching this video. So we will continue our discussion on the Indian tectonics, okay. Right now, we have seen the seismicity we will continue our discussion on the Indian tectonics from the next class onwards. Thank you very much.