Earth Sciences for Civil Engineering
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Module 3
Lecture No 15
Seismology and the internal structure of the Earth (Part-3)

Hello everybody. Welcome back. So in the previous lecture, we were talking about the and the earthquakes and then how earthquakes can be predicted.

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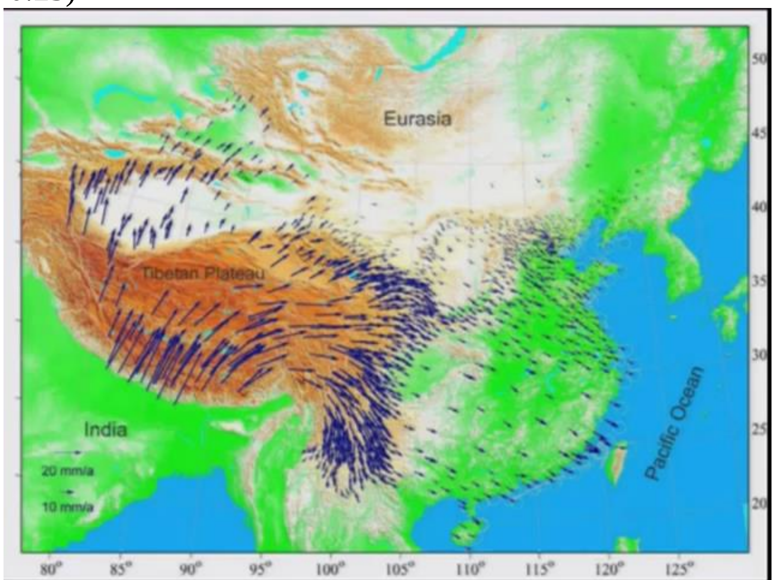

And then we talked about something related to the fault motion or the plate motions and the creeping **of** along the Hayward fault. Now let us move ahead and see how the earthquakes are measured and what is the importance, why we want to understand more about the earthquakes and all that okay.

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And few slides which we were talking about in the previous one that since if we know the location of the fault lines along which the earthquakes are likely to be triggered, then we can go for better constructions along those fault lines or close to those fault lines. So we need to know the location, exact locations of the fault lines.

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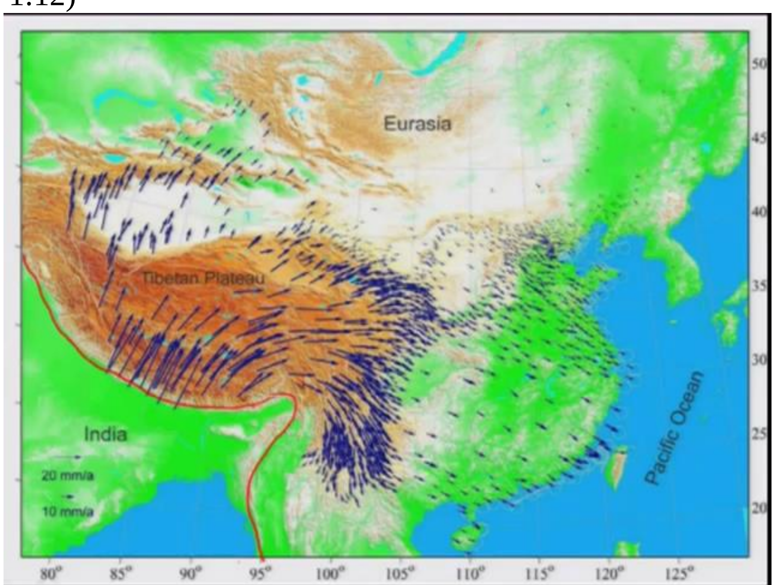

Now as I was discussing that we have now the GPS stations in most of the along the seismically active regions so that can help us in understanding that in which direction the plate is moving and at what rate the plate is moving. So this is an example which has been shown where we have the motion of the Indian plate which is moving in north north-east direction but and then the part of the Tibetan Plateau and the portion here it is not exactly moving in this direction but it is getting extruded okay.

So there is an extrusion of the Tibetan plate and the part of the Eurasian plate here okay. So this is the boundary between the 2 plates. That is your Indian plate and the Eurasian plate. This is what is the active plate boundary which goes over here like this actually. So this one, further down here in the south it will be in subduction zone. This is in collision zone where 2 plates are colliding with each other. So strain is getting developed here and and and periodically released along various fault lines okay in this region.

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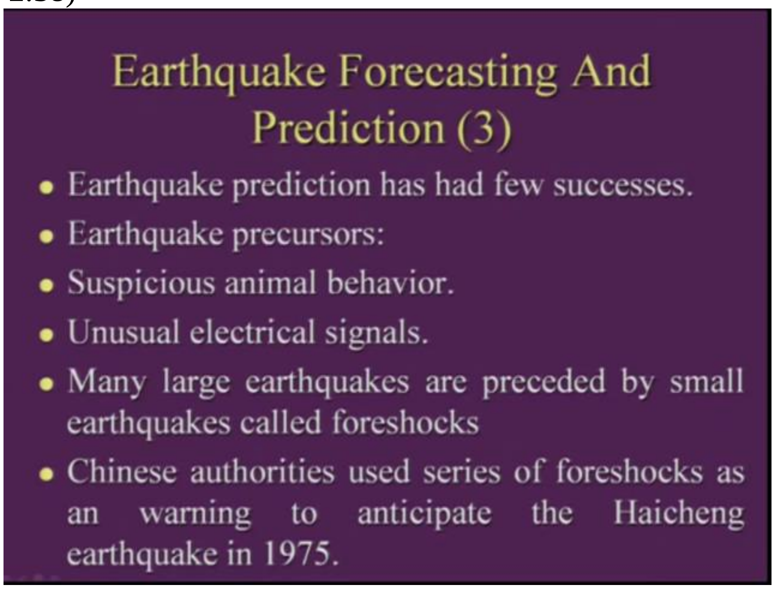

Now earthquake prediction further if we take, people have tried and had few successes in this. So earthquake precursors which many scientific groups have considered is that they will try to look at the suspicious nature of the or the behaviour of the animal before the earthquake. Then, unusual electric signals which has been noticed again because of the electromagnetic waves and in the beginning we were talking about that there is a magnetic field which has been generated by the inner core.

So there will be some disturbance of these the electric signals in the atmosphere. So that can be measured. Then, many large earthquakes are preceded by small earthquakes called foreshocks. So this is, before a major earthquake, there will be a series of small magnitude earthquakes which are termed as foreshocks. So if you closely monitor this, then you can try to predict that there may be a bigger event in this particular region or along the particular fault line.

But this all if you take, the suspicious behaviour of the animals, unusual signals, and all that, they are all short-term predictions okay. So you can have, window is very short where is a candidate. But this of course, you will have to very precisely keep on monitoring the earthquakes okay through using high-resolution seismometers. Chinese authorities used series of foreshocks as an warning 20 speed the Haicheng earthquake of 1975 okay.

So they were been able to identify and predict this event and save a lot of many people in that region okay. So in short, there are few successes in terms of the prediction of an earthquake. But still, a lot of work is going on to have to have an understanding that how best we can use the precursors which can tell us that there may be a big event in the coming future okay. Of course, GPS is one of the best way to understand the which area in which area the strain is getting accumulated and which area the strain is less accumulated okay. So we can at least say that the area having higher strain will produce a large magnitude earthquake in near future.

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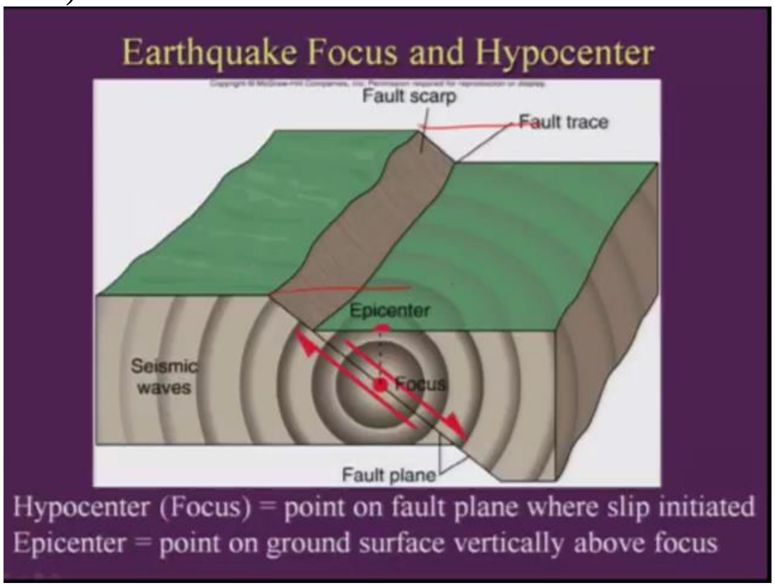

Then one can also have the probability that what are the chances of having the earthquake in that particular region along the plate boundaries or away from the plate boundaries and all that okay. Now along with the earthquakes, definitely this is the most important part with us because need to know and identify these signatures which are of such displacements which are taking place along the plate boundaries of away from the plate boundary.

So if you look at that the point at which the earthquake is triggered subsurface is termed as focus. And then the point exactly on the surface about the focus is termed as epicentre okay. And the surface manifestation where the displacement has occurred, please termed as the fault face and the landform which is developed because of the displacement is termed as fault scarp okay. So this we will see when we are talking about the active faults and all that.

So you will be able to understand. So what in short happens is that if you look at this layer and this surface and this surface were together at the same level before before an earthquake okay. So they were over here but got displaced during an earthquake okay. So this sudden displacement resulted into the release of an energy which is stored which was stored within the rocks and the displacement occurred along the weak zone okay.

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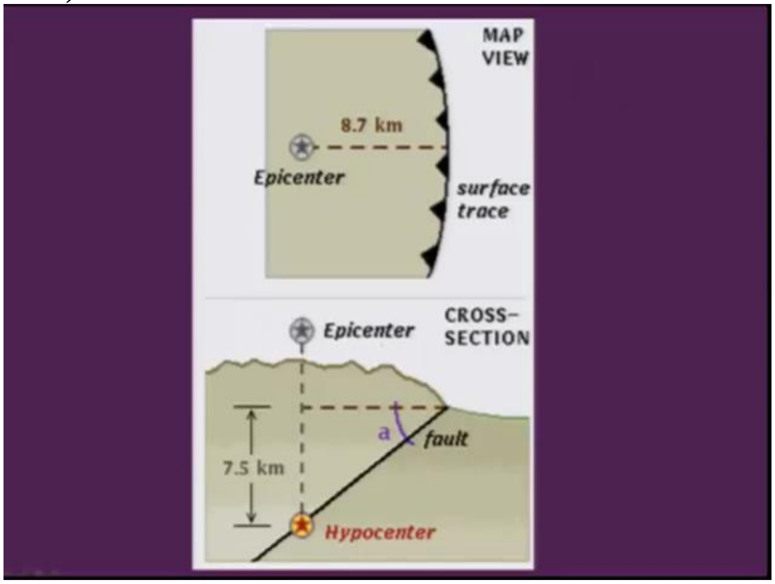

This is what has been just shown in the same part. That is we are having, either we call this a focus at which the energy is released along a fault plane and the exactly the point on the surface above the focus or the hypocentre is termed as epicenter.

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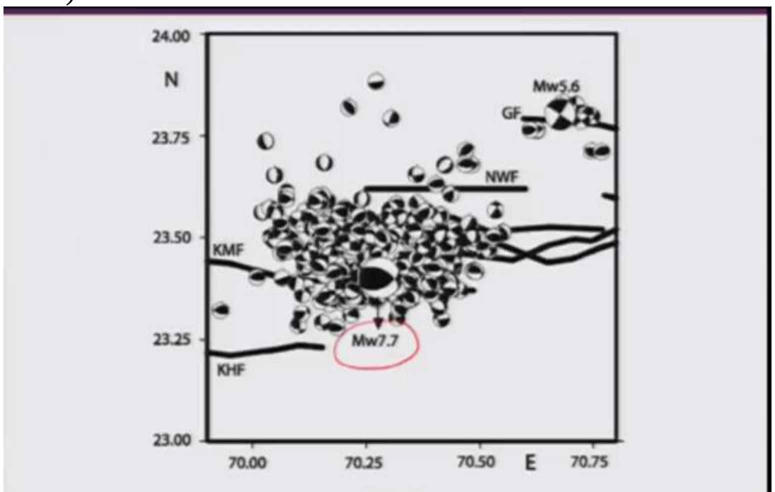

Figure 7

Spatial distribution of focal mechanisms across the Kachchh rift zone, Gujarat. Smaller beach ball represents solutions for the aftershocks of M_w 3.0–4.8. Medium size beach balls represent the focal mechanism solution for M_w 5.6 events. The largest beach ball marks the focal mechanism solution of the 2001 M_w 7.7 Bhuj main shock.

Now along with the main shock we will have many after-shocks over the foreshocks which have occurred here okay. Not this type of studies have been done to know that what is the extent of ruptured which occurred during an particular earthquake okay. So this is an example which has been given of an earthquake of Bhuj, magnitude 7.7.

So this was 2001 Bhuj earthquake. So main shock has been shown here and these are all all focal mechanisms which are showing is the after-shocks okay. So with the help of this, one can also identify that how deep was the fault triggered okay? So you can identify the depth of the fault deeply earthquake at which what depth the earthquake was triggered and how much area it covered in terms of the extent here okay.

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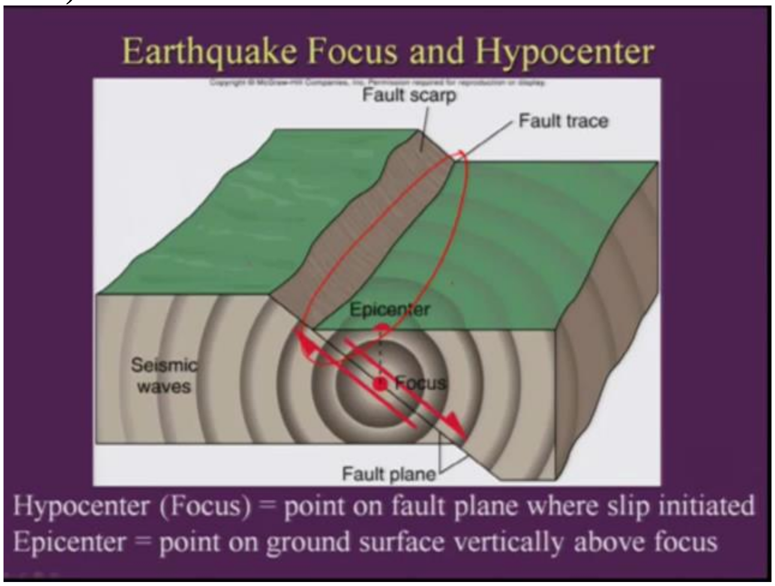

So one can also look at for example if you look at this one then whether the whole fault got ruptured or it was partly some portion was only ruptured here okay. So that, one can make out here.

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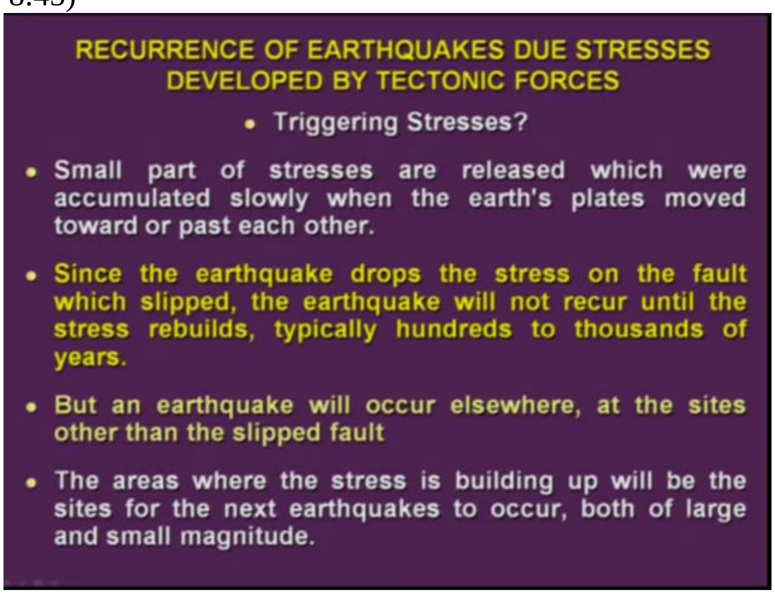

So recurrence of that earthquake due to stress by tectonic forces what we call the so this is another very important part which we need to understand, the triggering stress okay. So what we see is the small part of this stresses are released which were accumulated slowly when the earth’s plates move towards or past each other. So either they were moving towards each other or they collided or they slipped past each other okay.

Since the earthquake drops the stress or the strain which was accumulated on the fault which slipped, the earthquake will not recover until the stress is rebuilt. So next earthquake will not be triggered on that particular fault unless the required strain or the stress is built up along that and typically it may take hundreds or thousands of years.

So we know that at least in the Himalaya is, we have hundreds of years of recurrence between 1 earthquake to another earthquake. But this recurrence is on a particular fault. So if you remember or recall the slide where we were looking at number of fault lines in the San Andreas fault system where we have many fault lines having different slip rates okay.

So in particular fault it will have typical of the recurrence which may vary from hundreds to thousands of years. But once the stress is dropped, it will take time to rebuild okay that stress okay until the next event okay. But so you can remember that the diagram which we were talking about that this is a the period over which the stress will be built up and this will be dropped here and then we are having again building up and then dropped here.

So are the events which were having okay. Now further, but an earthquake will occur elsewhere at the sites other than the slipped fault okay. So along a particular fault, if there is an earthquake which has been triggered, but the mother fault line which is there, it may have potential of triggering the earthquake in near future. But this will take more time to have another event again compared to this one.

For example we say, this as A fault and this as B fault then if the earthquake has been triggered here, so this will take time to recur again. Whereas the B may have the potential of triggering an earthquake. So if you have the GPS station close by, we can understand that what is the strain which is getting accumulated in this particular region.

So now finally what we say that the so the areas of the stress is building up will be the site for the next earthquake okay to occur, both large as well as small magnitude. So this is what we can we can talk about.

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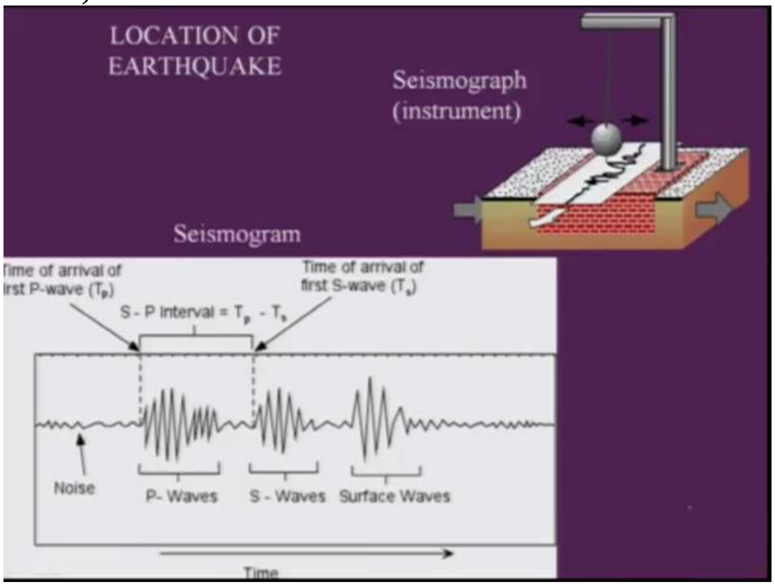

Now location of earthquakes particularly what we use are the instrument is termed as seismograph okay. And then we are having the information on which is been collected, that is the on the paper or a graph which is termed as seismogram okay where we measure or we identify the arrival time of P and S wave and then we take the time difference between the P and S wave arrival and then we also we will look at the amplitude of that which can help in identifying the earthquake okay.

So whenever there is an event, you will have more of zigzag lines here which we say the amplitude of the P and S waves.

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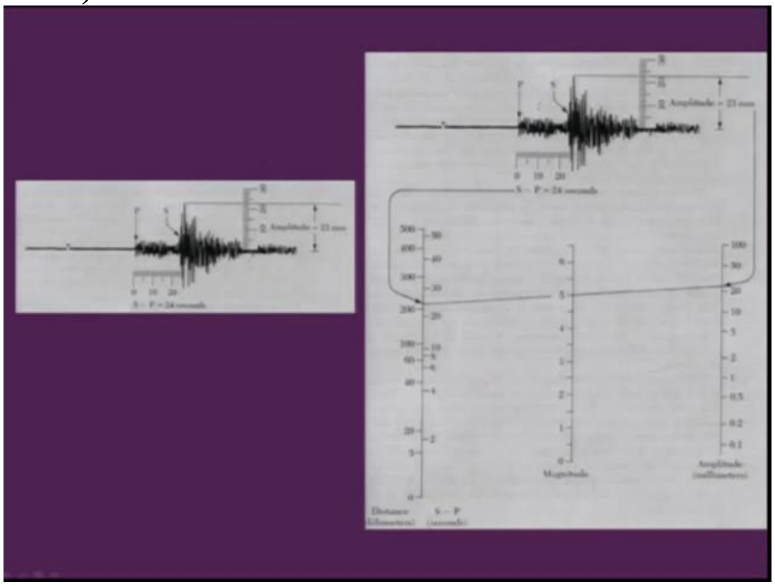

So this is one of the seismograph which explains how Richter scale is helpful in identifying the magnitude or knowing the magnitude of region okay. So you are having the P wave arrival. Because the P wave is the fastest, it will arrive 1st. And then you are having the S wave which came in. So this is the time difference between the arrival of S wave and the P wave, which is around 22 24 seconds here. And this is what we measure is the amplitude of the S wave here which is around 23 mm.

With this, Richter developed a logarithmic scale and then had an magnitude. So if you have the that is the difference between the arrival of P and S waves, which is around 24 and then you are having the amplitude which is around 23, so you connect this line, you will get the magnitude of that particular event okay. But now this computation is so fast that in no time, you will you will receive message or an email if you have registered on the USDA site depending on what magnitude earthquake information you would like to have.

Then immediately you can have that in couple of minutes having that information that what was the magnitude. So this is now has been done very fast with the help of computers and the programs or the softwares okay.

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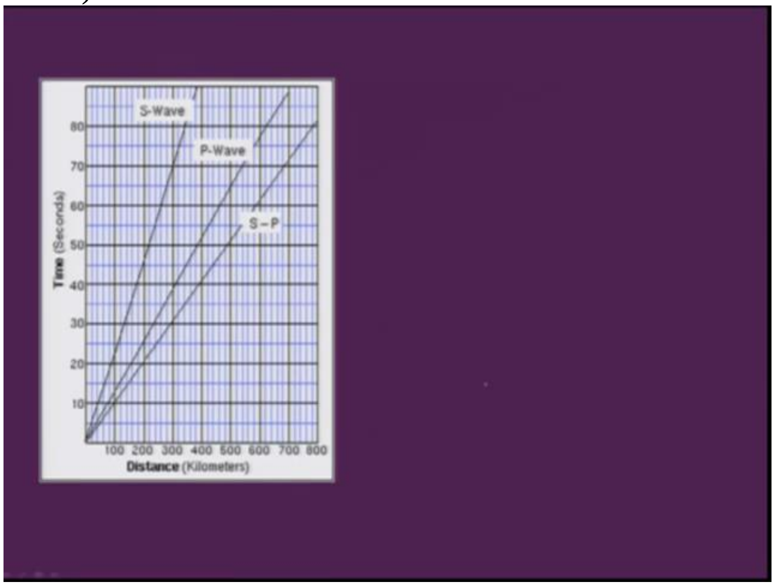

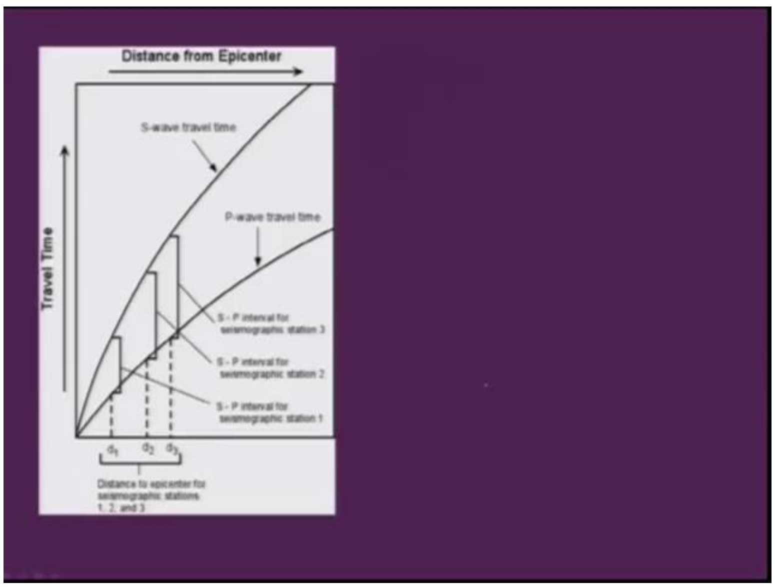

Now this is an concept what has been shown that how we can identify the epicentres. So again, having, you are measuring the that at different locations, you have different stations. And the you have the seismographs which are measuring the arrival of P and S waves. With the help of that, you can you can make out that what will be the epicentre of that particular earthquake okay.

So at least 3 stations are required to pinpoint the coordinates of the that particular event okay. So this shows that the calls which are available okay which shows the P waves arrival time and the S wave arrival time. And this has been like from different seismic stations. So seismic station 1, seismic station 2 and seismic station 3. So based on that the distance of to the epicentre has been picked up okay.

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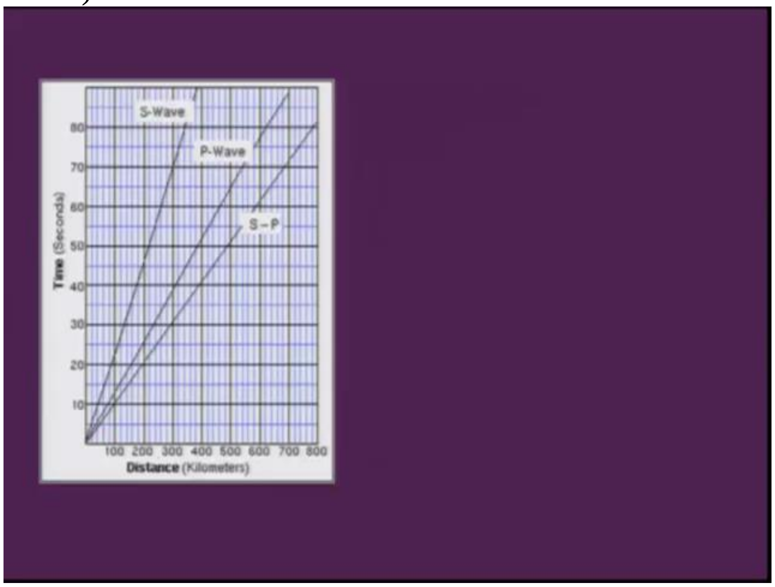

So you will get the distance from this one here. So you have these curves which we will talk about and then you just put the arrival time and then you will get the distance corresponding distance here.

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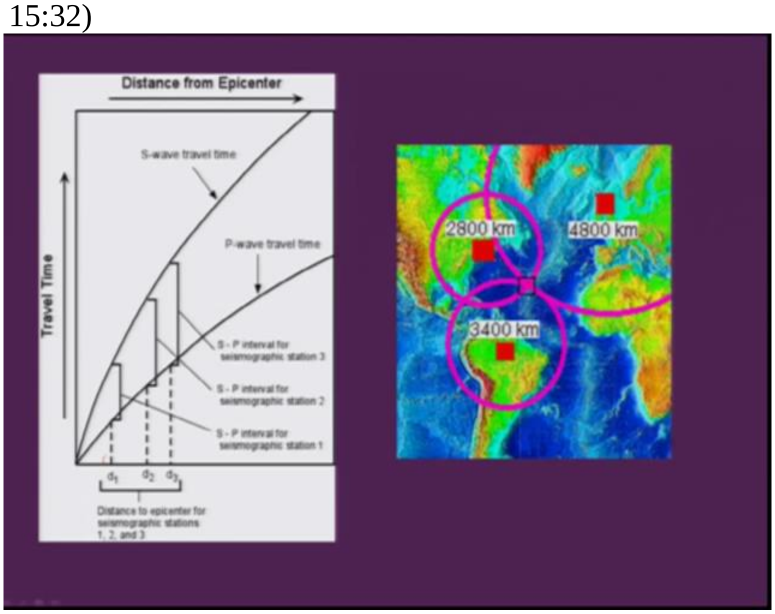

With the help of that, you can you are putting the circles and the intersection of that circle, 3 circles okay, we will give you the point which is your epicentre of that particular region okay.

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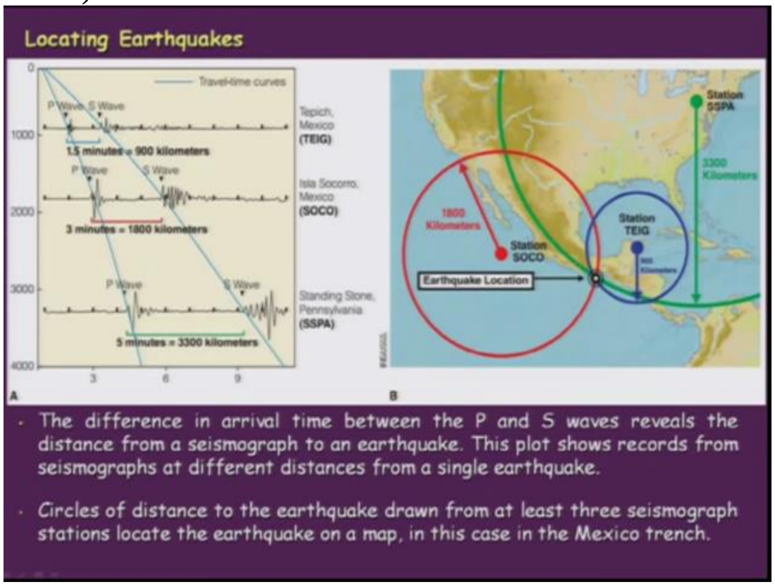

So this is again the same which shows the you have the curves which are available. And here, they have just put the different arrival times of different from or the data which has been put from different stations okay. You are having one station here. So this is the P wave arrival time, this is an S wave. So the time is here which is equal to 900 km.

And then you are having the 3 minutes which is around 1800 km and 5 minutes, 3300 km okay. So based on this, you put an circle of different areas and that will give you from the station, that particular station you will put an circle here. So this station, that is an SSPA had an 3300 kilometre of distance. So you have an circle that is a green line coming in. Similarly you are this TEIG, 900 900 km which comes here.

And then 1800 TEIG which is giving an, so this will be an intersecting point. Suppose sometimes that you are not having the intersection exactly here, so in between points will be taken and that is nowadays will be given as an tentative epicentre. But as and when more data comes, you can revise and have the precise one okay.

So this is how the epicentre is been measured again. This is an very fast process and in no time, you will get the information on your mobile or either in form of the email and all that where is the epicentre and what was the magnitude and all that okay.

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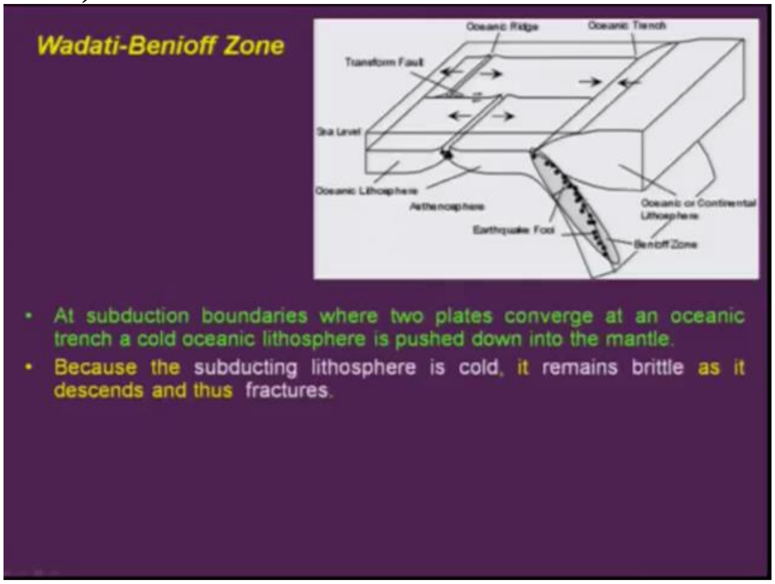

So this is one very important aspect which has been used to identify the fault rupture okay. And all the earthquakes which are been triggered, after the event are been measured and taken into consideration to know the rupture length that how far the rupture extended laterally and as well as at the depth okay. So this is what has been termed as the Wadati-Bernioff zone.

This is just to show that the focus but this is the pattern which has been showing that in the subducting plate, you will have the earthquakes which are been lined up to the greater depth okay and which can go up to around 700 km okay. So it can go up to 700 km. And and the and and this process that is Wadati-Bernioff zone is been termed a rare subduction boundary where the 2 plate converge at an oceanic trench.

A cool oceanic plate because the oceanic plate which is subducting down will be cool but similar process has been seen when an earthquake has been triggered okay. But particularly Wadati-Bernioff zone what it says or suggests that the cool oceanic lithosphere is pushed down into the mantle okay. Now because the subducting plate is cold compared to the what the temperature it has in the subducting area, it remains brittle at it descends and thus fractures okay.

Now fracturing will trigger small earthquakes, small magnitude earthquakes. And this zone is defined as the zone of earthquakes with increasing focal depth. Because the depth is increasing slowly. So plate is going down, it is fracturing and triggering the earthquakes. And so so focal depth will increase over the time. And that is termed as the Wadati-Bernioff zone.

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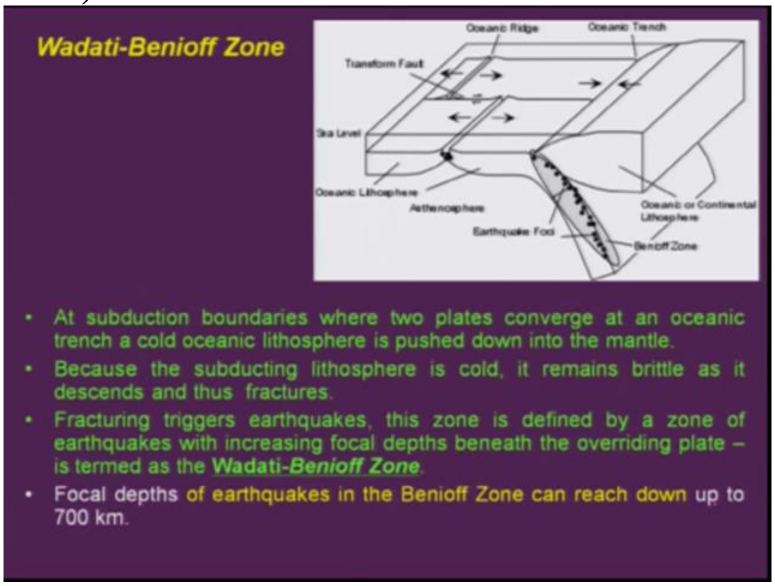

And as I told that it extends, the focal depths of the earthquakes in Wadati-Bernioff zone can reach up to as deep as 700 km okay. So this depth, measurement of depth is extremely important when we are talking about the earthquake because shallower earthquake will be more dangerous as compared to the deeper earthquakes okay.

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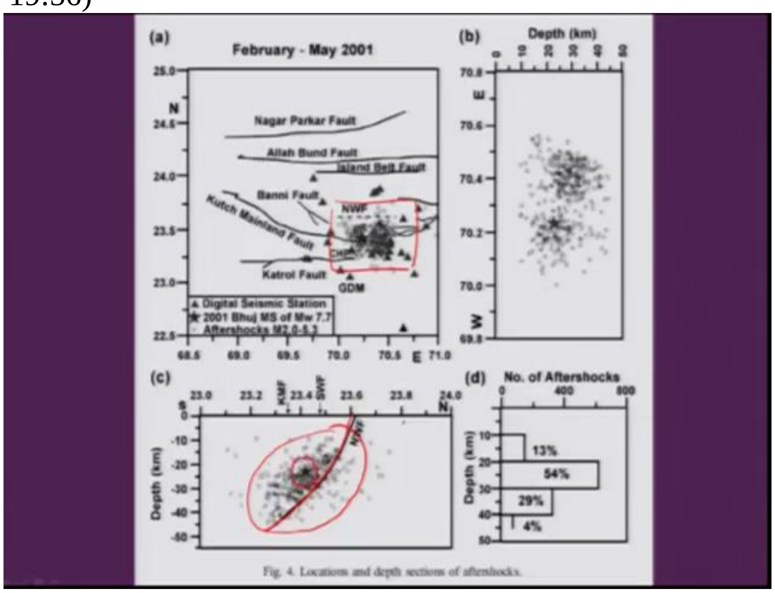

So this is an exercise which has been done for the 2001 Bhuj earthquake where you can see these different sections which are being prepared. This is a plan view which shows the area on the surface, how far it was been covered. Then this is the main shock here and you are having the other smaller earthquakes, after-shocks which are been triggered here okay.

And this is the depth section which shows that how deep was the earthquake which was triggered. So you can see here, the maximum depth is around 25 to around 30 km and the main shock was around 25 km okay. So this section again you see, the depth section and the surface, so you are having the main shock here and then after-shocks which are been confined in this zone okay.

And based on that, they have they have drawn a line which they say that it is an fault plane along which is the earthquake occurred okay. So this is how you can identify the depth of an earthquake, how deep it was. Whether it was shallow. But if you look at this one, this again, we say it was a very shallow earthquake of 2001.

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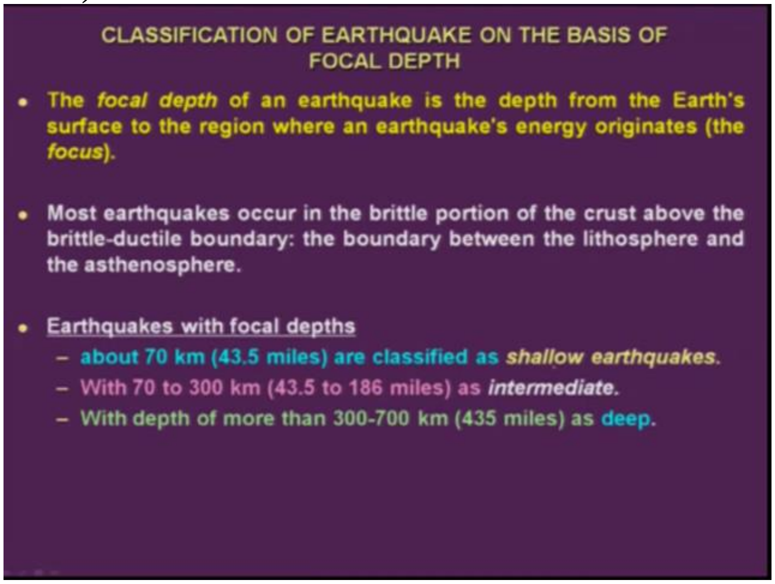

So classification of earth quake on the basis of the focal depth if we look at. So the focal depth of an earthquake is the depth from the Earth’s surface okay. So it is the depth from the Earth’s surface to the region where the earthquake energy originated. So that is the point, that is the focus from where or the hypocentre from where the energy was originated okay or release. So most earthquakes occur in brittle portion of the earth’s crust above the brittle ductile boundary.

And the boundary between the lithosphere which is the lithosphere and asthenosphere okay. And then earthquakes with focal depth if you have to classify this, so about 70 km depth if you take are classified as shallow earthquake. And if you are having around 70 to 300, they are intermediate. And more than 300 to 700 km, are the deep earthquakes okay.

So as I told that this is extremely important to know that what is the pattern of earthquakes, whether it is intermediate or it is deep earthquake in any particular region physically along the plate boundaries. That is extremely important to know. As I told that shallow earthquakes will be more damaging as compared to the deeper earthquakes or the intermediate earthquakes.

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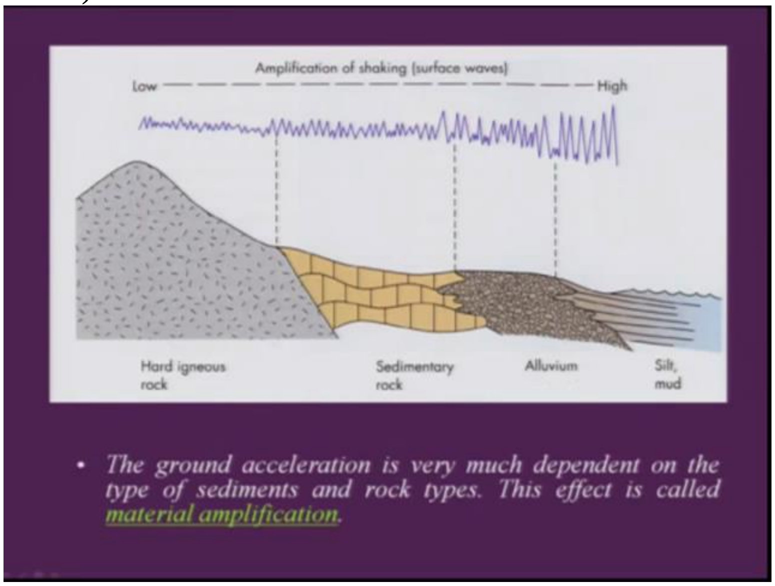

Now this is what is another most important important part is that when an earthquake is been triggered, it will result into the strong ground shaking okay. And in some places, depending on the material okay, what type of material we have, that is the lithology what we say the amplification will be experienced in a different form okay. So for example, if you are having hard igneous rocks and you are so you will have lesser amplification of the seismic waves.

But if you are having sedimentary rocks, you will have little more. And if you are having loose material, what we call the alluvium and further the finer deposits, we may have very high amplification okay.

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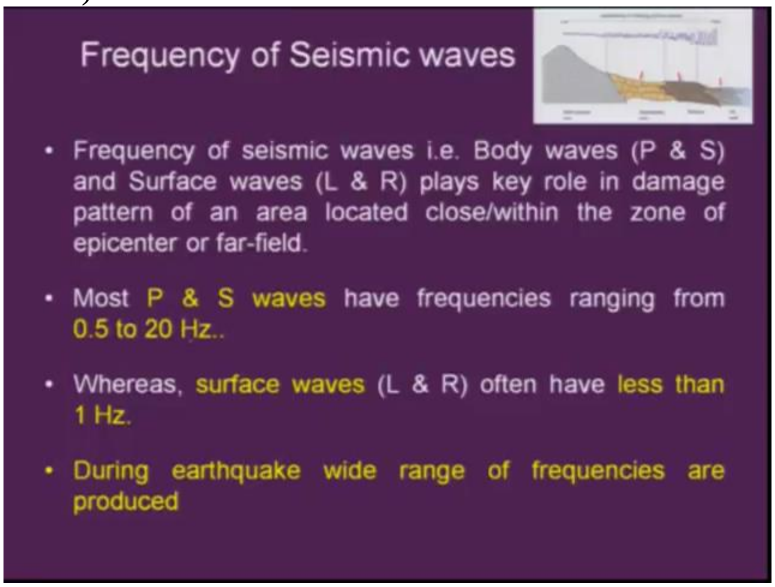

So the ground acceleration in (())(23:35) areas are are the regions where we are having like which are sitting away from the epicentre regions okay. So most of the P and S waves what we see okay are having frequencies ranging from almost 0.5 to like 0.5 to 20 Hz okay. So this is one very important part which you should remember okay. So the surface waves in particularly what we are having, the L and R waves, that is the love and the rayleigh waves often have less than 1 Hz frequency okay.

So this have the range, 0.5 to 20 Hz. So very wide range is there but this is having very less, almost like 1 Hz here. So during an earthquake, wide range of frequencies are produced okay. So we have like what we see here, 0.5 to 20 Hz we are seeing. That different, very wide range of frequencies are are been produced.

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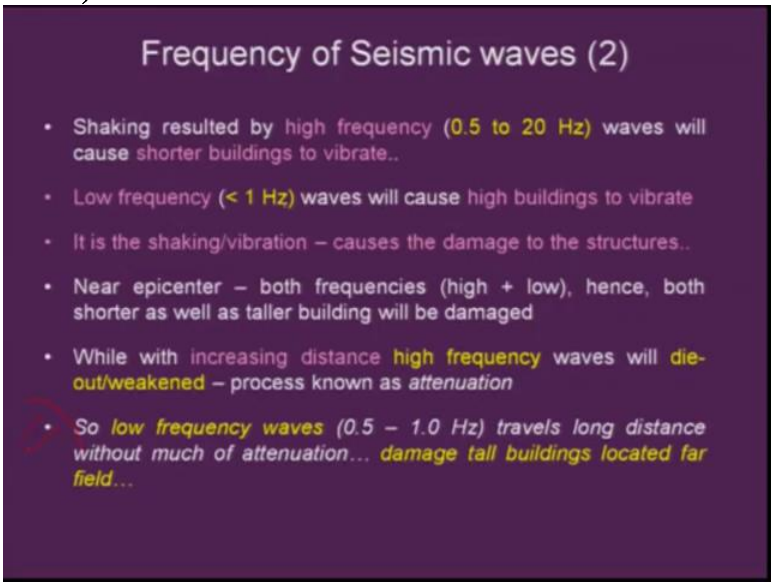

Now shaking results by high-frequency. That is the 0.5 to 20 Hz waves will cause short buildings to vibrate. So the shorter buildings will will be affected by the body waves okay. Whereas the low-frequency waves this is the what we are talking of, the surface waves will cause high buildings to vibrate.

So if you are in the epicentral area, you will definitely have both the all the frequency waves which are been generated and so you can have the vibration of the shorter buildings as well as the taller buildings also here okay. Now it is the shaking or the vibration that causes the damage to the structures. So near epicentre or within the epicentral region, both frequencies that is high and low, so both high as well as low-frequency waves will be experienced.

Hence both shorter as well as the taller buildings will be damaged here. While with the increase of distance because there is an epicentre and then the waves will travel farther away, so as you have the increase in distance, high-frequency waves will die out okay. So the body waves will die out and get weakened. This process is known as attenuation. Whereas low-frequency waves which are still there, which we say then ok 0.5 and less than 1 Hz what we are having travel long-distance without much of an attenuation.

So the surface waves will travel much farther okay. And damages the tall buildings located even far okay. So we say that ok fine, we are not in the epicentral zone so then we will not be affected and we can have high-rise buildings. You are safe sitting faraway from the epicentral within or the source region of an earthquake but that is not true.

The taller buildings will be affected by the surface waves mainly having frequency which is less than 1 Hz. So this is one of the important part is which you should remember that the different frequencies days are been generated during an earthquake and and which will affect the taller as well as the shorter buildings okay.

So I will stop here and we will continue with the more details in the next lecture talking about the different type of earthquakes in different regions. That is what we call the inter plate earthquakes and intra-plate earthquakes and then we can also talk more about the magnitude and the intensity scale. So we will continue in the next lecture. Thank you so much