Earthquake Geology: A tool for Seismic Hazard Assessment

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Lecture # 17
Earthquake Forecasting and Prediction Model (Part II)

So, welcome back. So, in previous lecture we discussed about the forecasting and prediction of earthquake and there were few successes which were been achieved in prediction or forecasting the earthquake 1 was the 1975 Haicheng earthquake of China and there was another 1 is from Himalayas. So, today we will discuss about this and will move further in this lecture.

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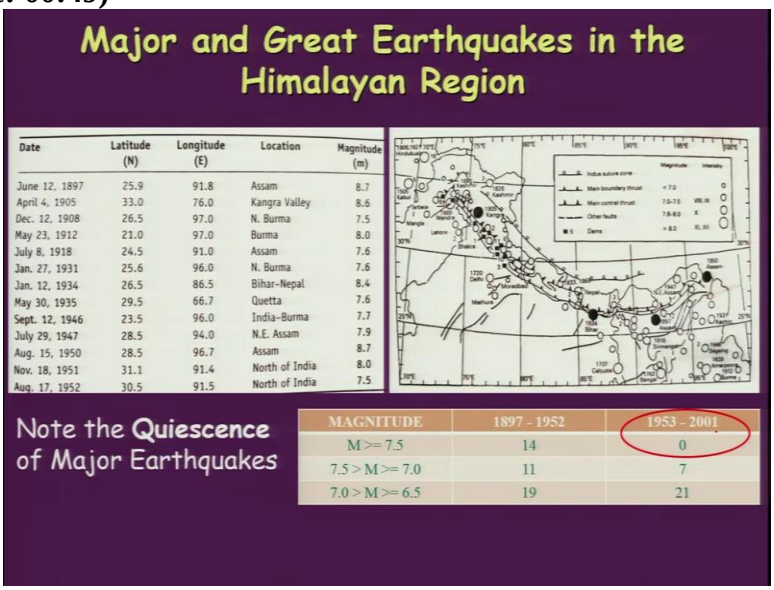

So, as we discussed in the previous one that really very true sense of the large magnitude earthquake greater than equal to 7.5 between the period from 1953 to 2001.

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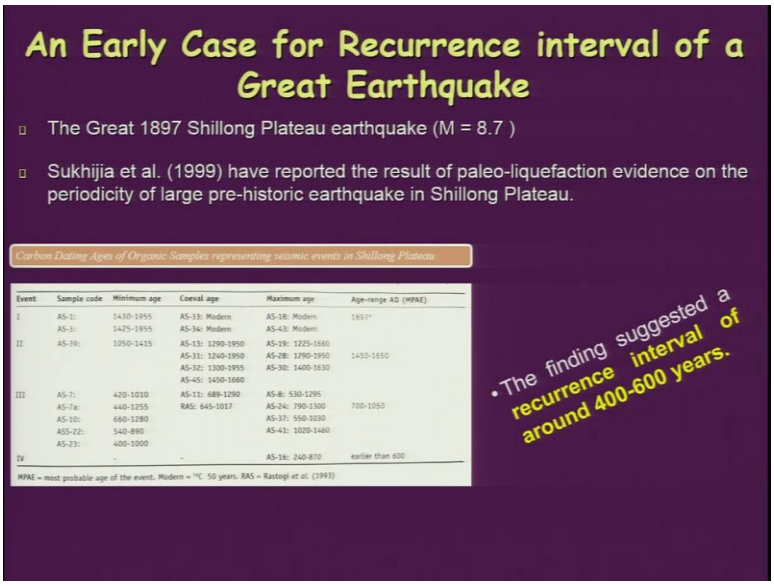

So, an early case of a recurrence interval, the other studies which were been taken up in the areas like the affected area by Shillong earthquake, which was in the 1897, but magnitude 8.7 the group from national Geophysical Research Institute NGI, Dr. Sukhijia and his team have reported the result of paleo liquefaction. So, these are the secondary effects, which will always get preserved in the sediments and this is because it is related to strong shaking.

So, the found the evidence and the periodicity of the large prehistoric Earthquake in this region and based on the radiocarbon ages of collected the data from the charcoals collected from different units, which were been deformed due to the liquefaction process. What they suggested was that the recurrence interval and this region is almost like 400 to 600 years.

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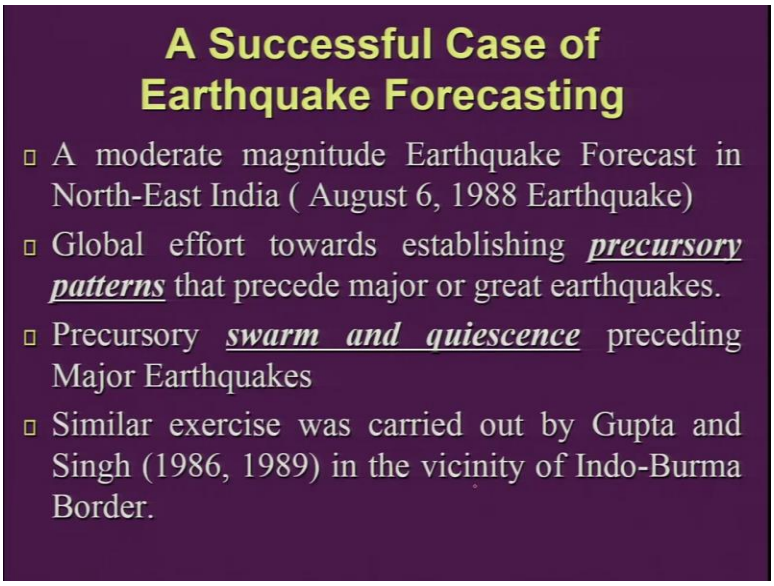

So, this study was been done in the area of not East India in Himalayan region, a moderate magnitude earthquake forecast was been done. And this was when 1988 this was been done in 1988. So the global effort towards establishing the precursory pattern that precede major and great earthquake. So, this is what was been taken into concentration for the hygiene earthquake also that the precursory events were been consider for predicting the preceding major events.

So, a swarm of and the quiescence preceding major earthquake also is an indicative of but so, either there is number of earthquakes. Now, a large number of earthquakes have started occurring in a particular region or there is a quiescence there is no earthquake, which has been recorded since last 100 years or 50 years or so, those areas are the areas which will be hosting the last minute magnitude earthquake.

So, considering this either it is on swarm or the period of questions and taking into consideration the process of precursory events. Similar exercise was carried out by Gupta and Singh in 1986 and 1989 in the vicinity of Indo Burma border.

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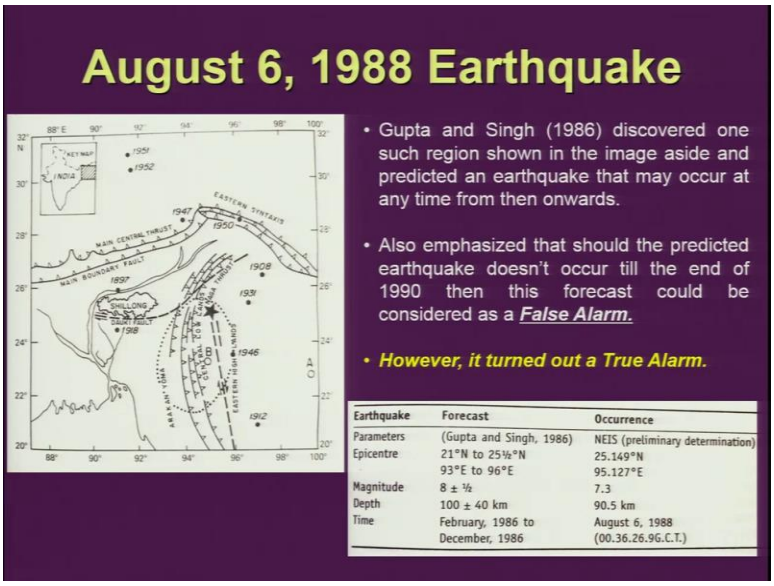

Now based on this August 1988 earthquake was been predicted. So, other the Northeast portion of India with the previous record, it suggested not there was an earthquake in 1897 and then another one was here in 1950 and few more which have been listed here 1947 1905 1931 and all that. So, in this region the, this was when predicted the earthquake was been predicted. So, Gupta and Singh in 1986 discovered 1 such region shown in the image this is 1 side and predicted an earthquake that may occur at any time from then onwards.

So, they suggested that during their studies and carried out in 1986. So, after this, anytime there will be an earthquake in this region and what they also suggested that this is this was difficulty based on the precursor events. So, they emphasize not this event and that should be predicted earthquake does not occur till the end of 1990, then this forecast could be considered as and false alarm.

So, this uncertainty always remains with the observations or with the studies which are or the investigation which are carried out considering the precursor events, but at least if there is an the forecast based on such studies will alert the people in the local area or the respective areas where this such predictions have been done, and precautionary measures can be taken up well in advance.

If it is false alarm it is well and good, but if it occurs then we are towards the safer side. So, however, it turned out a true alarm and there was an earthquake which occurred when on the forecast was this one and the occurrences over here. So, what they suggested that this will be the region where the earthquake will occur and the magnitude will be around 8, + - 5, 0.5 so, but the earthquake occurred in this area as compared to what it was then given the region here which was pretty much within the registrant of area.

If you can see this one here, replies very much close to this one. So, it was detected within that, and the depth also has been predicting that the depth world will be around 100 kilometers on the surface and the depth was 90 kilometers which was and time which was been given was between like from 1986 and December 1986. And the earthquake occurred in 1988 on August 6. So, this was again another successful achievement which was been done based on the precursor event.

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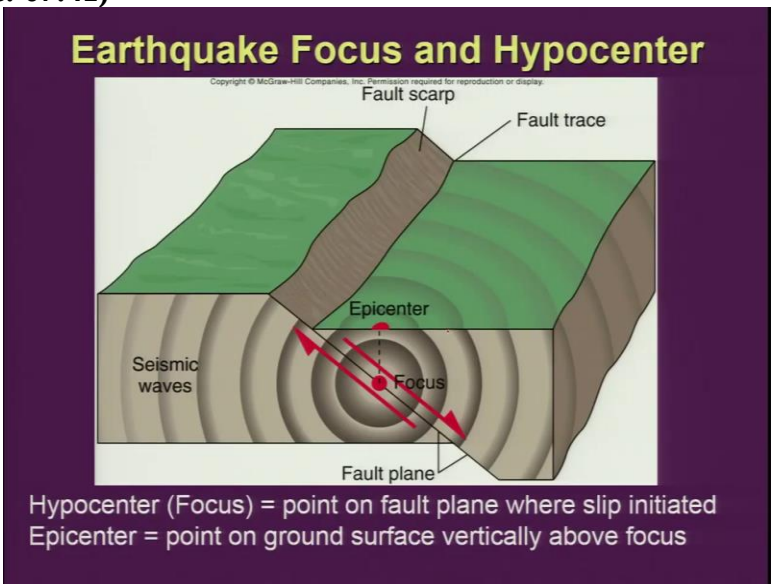

Now vertical focus on Hypocenter. So, wherever there is a maximum amount of energy has been released at a particular point that is termed as your focus on the fault plane. And the exactly the location on the surface is been termed as epicenter and the displacement which is been observed on the surface, if there is an displacement coming right up to the surface and the deformed surface has been that manifestation of the deformation has been termed as fault scarp and the line here along which moment has taken places the fault line.

So, this will be the fault plane, this will be a fault line and they displaced surface is your fault scarp. So, the energy where it has been released, the stored energy at depth is termed as focus and the point exactly on the surface about that is your epicenter. So, for us everything that is all this points are important to know that what up the earthquake will take place. What is the epicenter of the fault lines whether we see the signatures which are preserved in the landforms on the surface that is your fault scarp and all?

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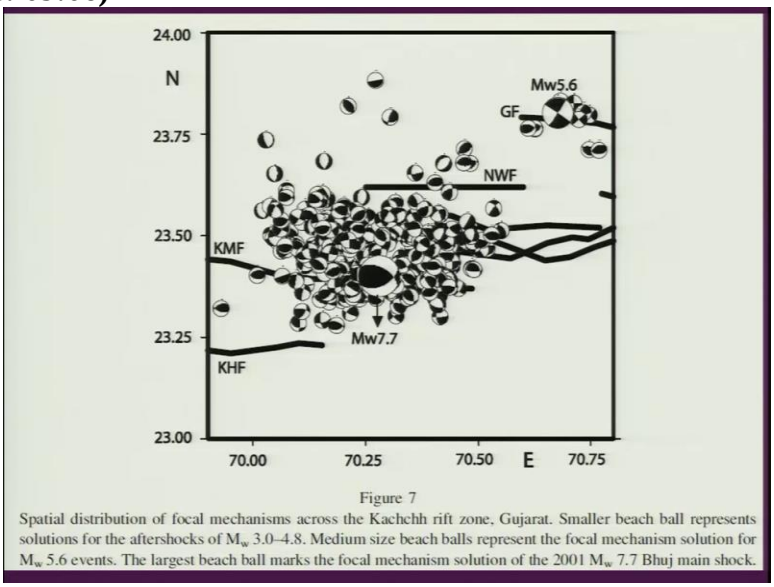

Figure 7
Spatial distribution of focal mechanisms across the Kachchh rift zone, Gujarat. Smaller beach ball represents solutions for the aftershocks of M_w 3.0–4.8. Medium size beach balls represent the focal mechanism solution for M_w 5.6 events. The largest beach ball marks the focal mechanism solution of the 2001 M_w 7.7 Bhuj main shock.

Now, depth one can easily pick up.

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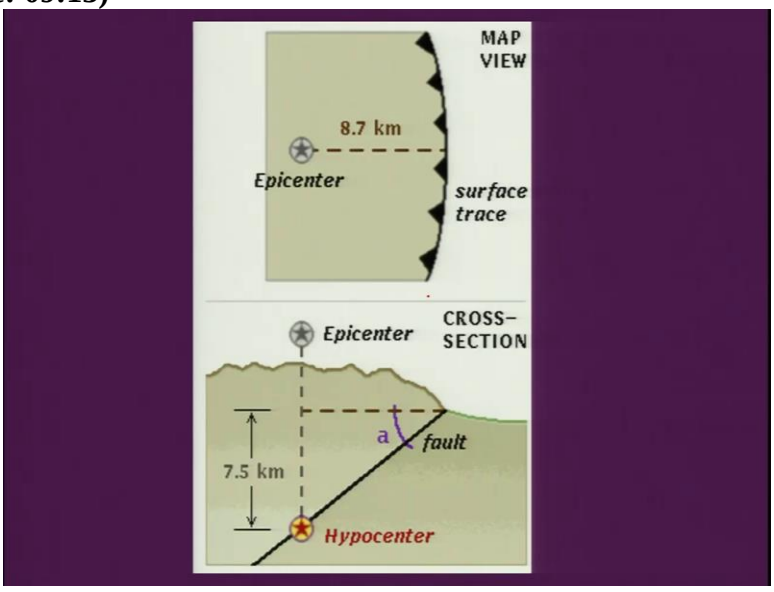

Because this helps in understanding that what is the pattern of all things. Because whether the fault is dipping in this direction or the fault is dipping into this direction this one can pick up based on what is the depth. So, exercise simple exercise can it has been done considering the distribution of earthquakes now, this is the case with 2001 which was quake occurred, and these are all aftershocks. So aftershocks had been distributed in the area, then which would have got ruptured that is subsurface.

So what do you see as this is of course is the plan view. You see the distribution around the latitude longitude and the location of those epicenters. And these are all beach and ball diagram, which also indicate which type of moment has been observed along this one either the block has moved up or either the literate has laterally moved or it has moved down.

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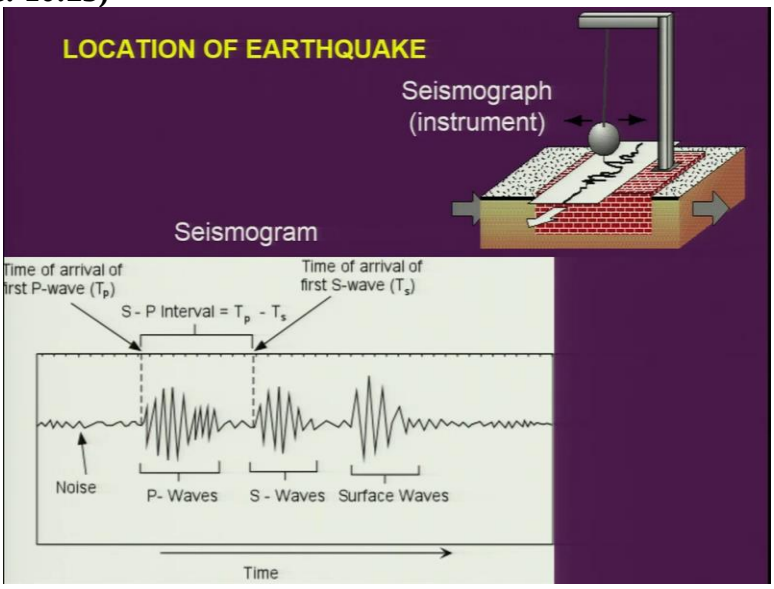

So, the location of earthquake is been done as have briefly discuss, that the instrument which has been used to record is been termed a seismograph and the recorded graph which we get is been termed as seismogram. And this is mainly where the arrival time of the difference between the arrival time that is an essence between the S and P wave or you take between the love and Rayleigh wave they take this the difference has been taken into consideration along with the amplitude to locate the epicenter.

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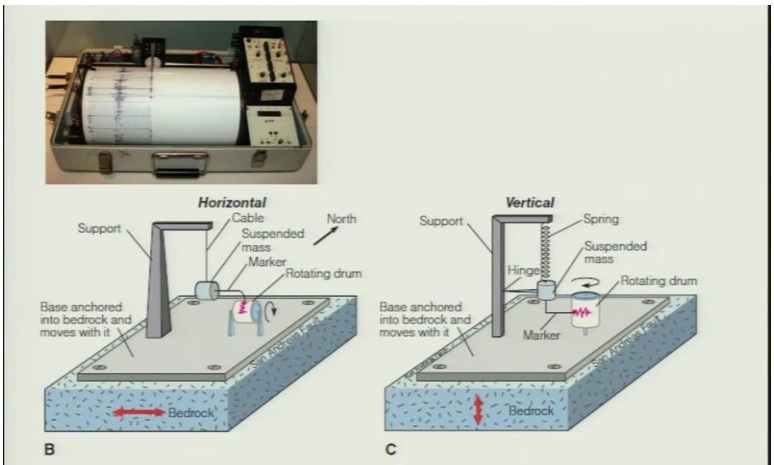

FIGURE 3-24 RECORDING THE SHAKES

A. Although many seismograph stations now record earthquake waves digitally, a recording drum seismograph, like this one, is especially useful for visualizing the nature of earthquake waves: their amplitude, wavelength, and frequency of vibration. Different seismographs are used to measure, for example, **B.** horizontal versus **C.** vertical motion and small versus large earthquakes.

So, there is another diagram along with that, which shows not only the location of the epicenter is important, but for the civil engineers and as well as the seismologist, they will be interested in knowing that what is the amount of horizontal movement and what is the amount of vertical movement which has been taken. So, this it shows that this the horizontal movement and then what will be the vertical movement.

So, this basically records the ground shaking. So, although many seismograph stations now records earthquake wave digitally recorded from a seismograph like this one, especially used for visualizing the nature of earthquake waves that is mainly the amplitude, wavelength and the frequency of the vibrations. So, different seismographs are used to measure for example, which has been shown in B horizontal version and the vertical motion.

So, the vertical as well as horizontal motion is also important, because that will help us in understanding that if a particular earthquake has been triggered on in any given region, then what will be the effect to the site of interest where we want to do go for seismic hazard assessment.

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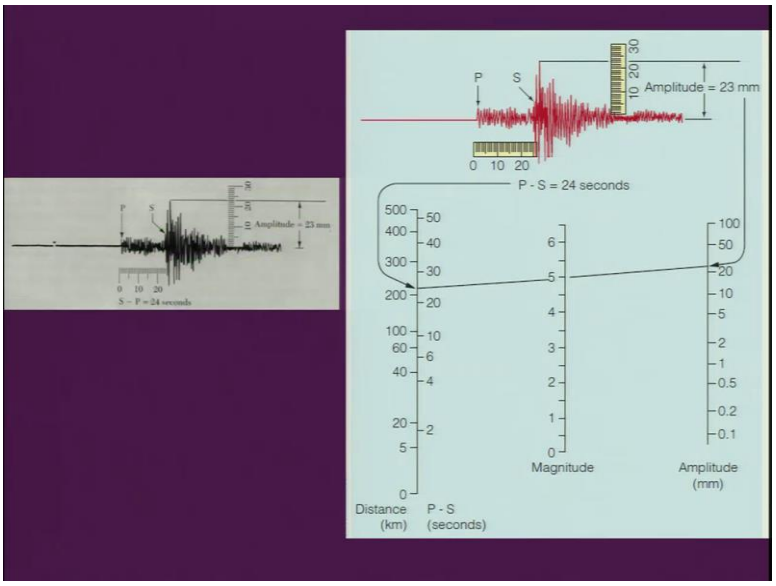

So, basically if you are having the seismograms. So, the difference between the arrival of P wave and S wave has been taken into concentration and that helps and along with that the amplitude has been taken into consideration. So, the example which has been given here, where it shows that you have considered the amplitude of the arrival of the different seismic wave, but mostly it has been taken as an S wave arrival, because this will return to the major deformation.

The P wave was mostly the compressional, but this one is the shear waves that is an S wave and the difference between the arrival So, this will be arriving first and this will be later and the difference has been taken here and this is an log scale which helps in locating that or identifying the magnitude of the earthquake. So, you have the amplitude here you have the time difference and connecting this 2 points will give you and the chart will give you the magnitude and what will what was the magnitude of that particular earthquake.

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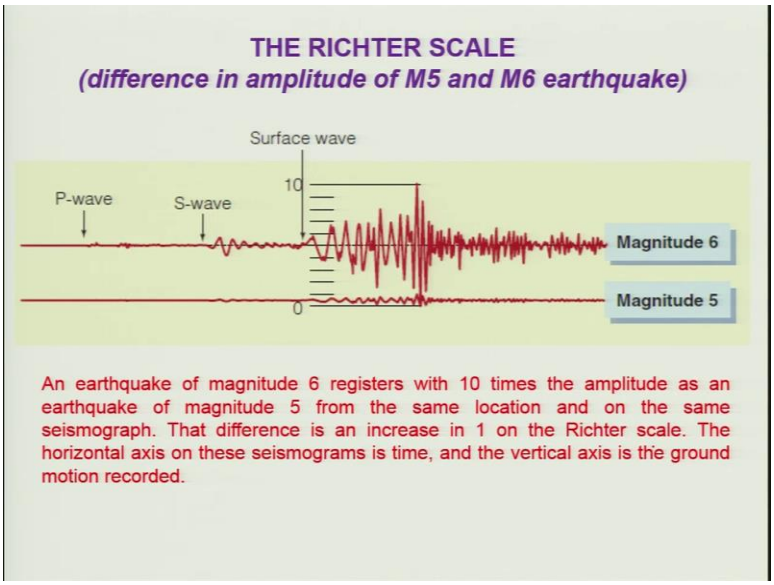

So, the Richter scale if you take the because the amplitude will play an important role what we are seeing here the difference between the magnitude 5 and 6 is very large and that what is spin and we all know that the magnitude if we have between 5 and 6 then the energy which has been going to be released will be almost like an factor of 30. So, here we have the magnitude 6 amplitude, which we see here is quite comparatively larger as compared to what you have the magnitude 5.

So, it is it says an earthquake of magnitude 6 registers with 10 time the amplitude as an earthquake of magnitude 5 from the same location and this is the just the differences one on the Richter scale.

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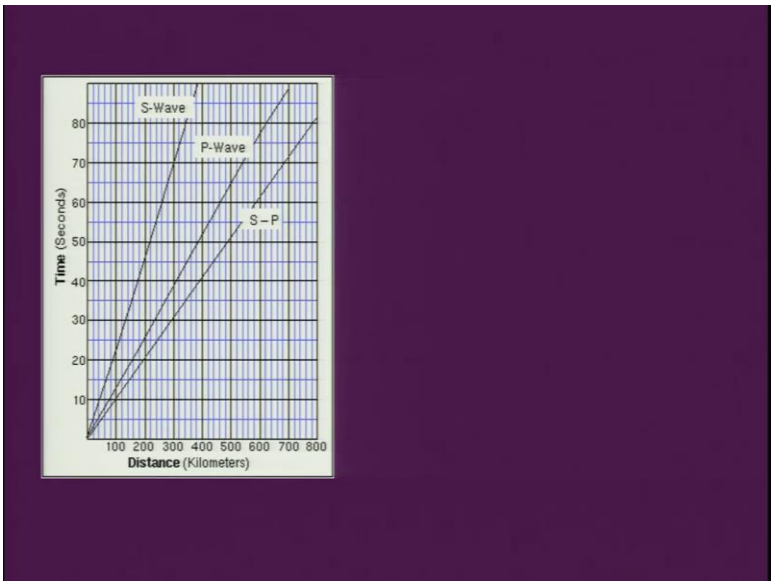

Now, if you have a like, because the important part will be to keep the earthquake that is an epicenter on the surface. So, at least you need 3 stations 3 seismograph that will help you in locating the earthquake.

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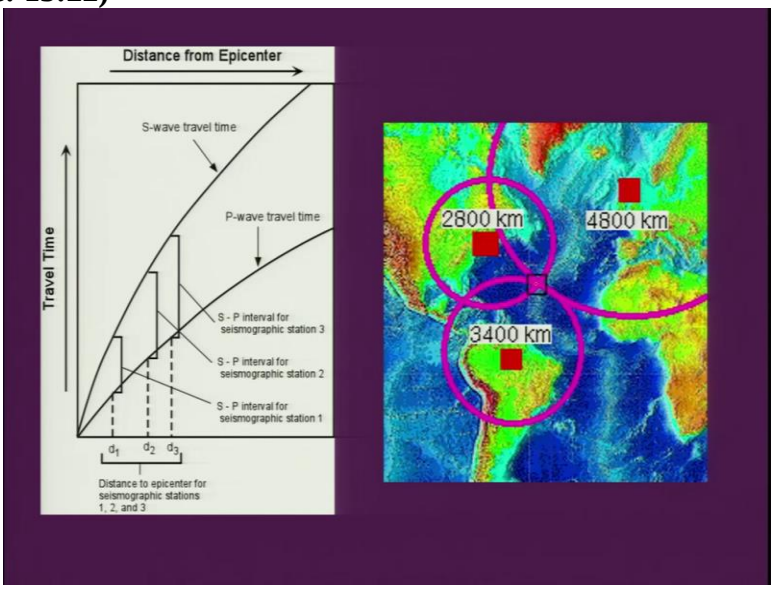

So, if you this are standard diagram, the curves which are available, which helps in locating the earthquake. So, you have the, if at least you have the arrival time difference between the arrival times of P and S with 3 different location you can calculate the distance and that distance is you are would call the radius can plot it based on that and that the intersection of this 3 points will 3 circles will give you the epicenter.

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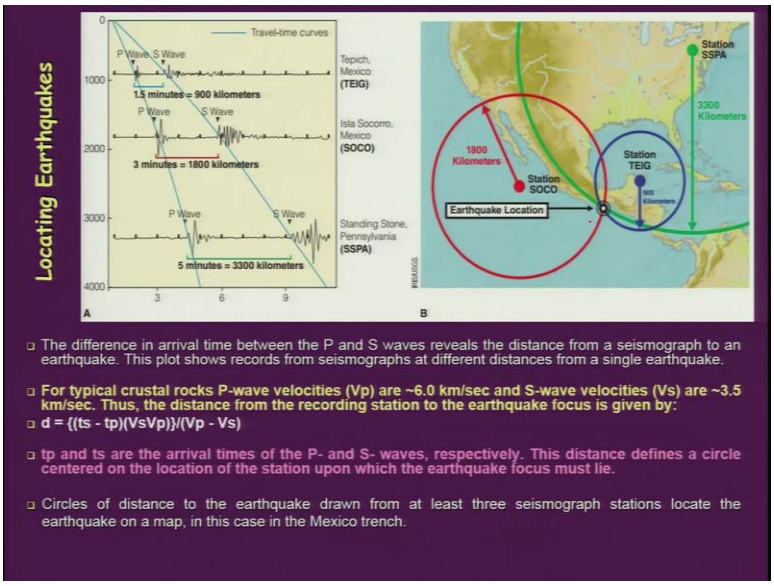

So, locating earthquakes basically you have like 3 locations which are one given here. So, you have 1 station which is sitting and SOCO then TEIG and SSPA. So, these are the 3 stations which were used to locate the epicenter of 1 particular earthquake here. So, what it shows on this curve here or this graph that you are having the distance here this is you are the time difference. So, you have the first P wave which is arriving here was at 1.5 minutes.

And the distance result was been calculated between the differences is here is 1.5 minutes which is equal 900 kilometers and the this has increased the time because the from the epicenter of the wave have traveled. So, the time interval has increased. So, this is around 3 minutes 1800 kilometers and further if you go away that is your SSPA this 1 is SSPA the time interval is almost like 5 minutes and that has given the larger distance from the epicenter.

So, as you move away from the epicenter, so, suppose the earthquake has been triggered here. So, the arrival time at this station will be comparatively less here will be a little more and this will be the largest one. So, that is what we one can observe based on the arrival time difference. So, the difference in the arrival time between the P and S wave reveals the distance from particular seismograph.

And had to an earthquake now is the distance from here to this one here. So, this plot shows the record from seismographs at different locations or different distances from a single earthquake

for typical crustal because the time interval is almost remains in that because the first arrival and the seeker the arrival of P wave and S wave depends on because of the and the nature of the P and S wave traveling through the different medium.

And in crust mostly what we see as the travel the velocity remains around 6 kilometer per second for the P wave and around 3.5 kilometers for the S wave does the distance for the recording station to the earthquake focus as given by so, this is an equation which has been given which can help you and calculating the because you need the time and you need you know the velocity which has been given here.

So, based on that, this is the ts is the they travel time for the that is the arrival time of you are S wave and this is P wave and then you can use the values putting in this equation and identify the in d distance. So, the tp and ts are the arrival time of P and S wave respectively, this distance defines a circle centered on the location of the station upon which the earthquake focus must lie. Now, in some places some stations will not allow you exactly to have an intersection here.

So, the in between area is been taken initially as an epicenter and then with the data coming from more stations because not all regions will have at minimum 3 stations they might be having more stations. So, if more data comes in, then you can refine the location of the epicenter.

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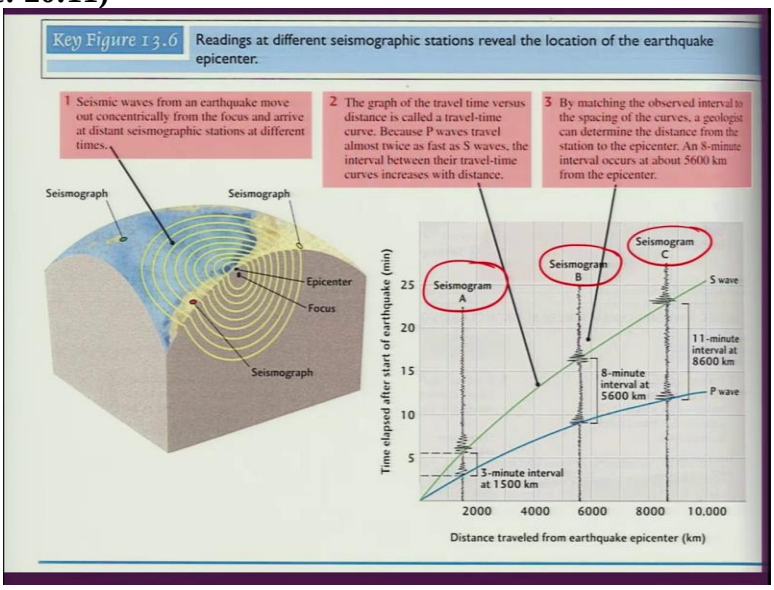

So, this is the similar example which talks about the different seismographic stations reveal the location of earthquake epicenter. So, a seismic wave from an earthquake moves out concentrically from the focus and arrives at distance seismographic stations at different time. So, as we were talking about that if you are having the different located seismograph, then you will have that they will arrive at different time. And then the second one, it tells us not the graph of the time interval.

So, you are having the time interval here, which has been given here and then you have the distance which has been highlighted here the previous diagram was also more similar, so, what we see as the travel time versus distance is called the travel time curve. So, we have the travel time curves available, because the P wave travel almost twice as fast as the S wave. So, this will arrive first and this will arrive later. Because this the velocity is around 6 and this is almost around 3.5 or so, the interval between their travel time cause increases what distance so, that what was been explained in the previous slide also.

That in the arrival time here is will be less because they are close to the epicenter and by the difference between the arrival time increases as we move away from the epicenter. So, by matching the observed interval to the spacing of the curves the geologist or the seismologist can determine the distance from station to epicenter an 8 minute interval occurs at about 5600 kilometers from the epicenter, which has been shown here. So, if you have 3 minimum points, then 1 can easily locate the earthquake epicenter.

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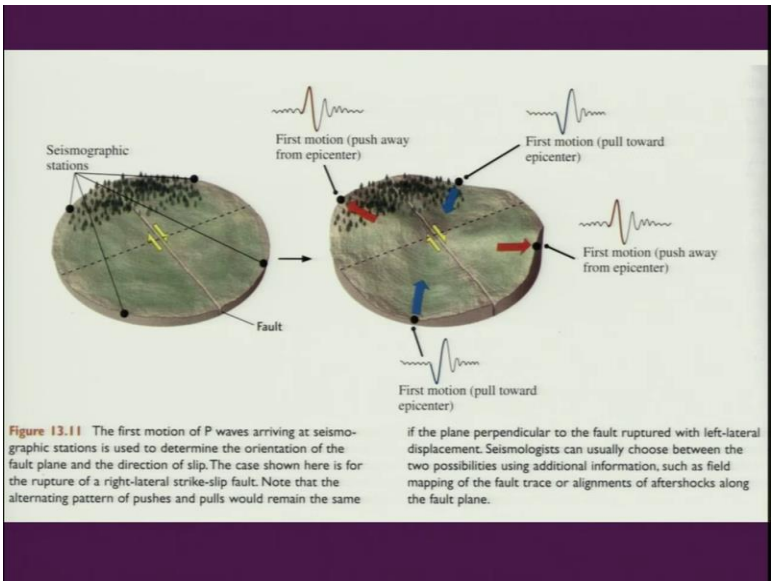

Figure 13.11 The first motion of P waves arriving at seismographic stations is used to determine the orientation of the fault plane and the direction of slip. The case shown here is for the rupture of a right-lateral strike-slip fault. Note that the alternating pattern of pushes and pulls would remain the same if the plane perpendicular to the fault ruptured with left-lateral displacement. Seismologists can usually choose between the two possibilities using additional information, such as field mapping of the fault trace or alignments of aftershocks along the fault plane.

Now, since we have like very fast computing facilities and algorithms which are available with us, so, this seismographic stations can now very quickly calculate and tells us that were exactly the epicenter is located. So, in no time maybe in few minutes or maybe been less than a minute you will get the location of the epicenter along with that, this is another exercise which has been done is you are identifying the different type of faults of the slip which has occurred.

And this has been done considering the arrival of the first motion, now the arrival of the first wave, Now, not all the stations will have the similar arrival that is your what you are having here positive wave material first motion is your negative and so on. Now, this will indicate that what is the pattern of movement which has occurred on that in that particular region? So, what it shows us here, you are having the fault line and at least you have the fault stations for example, which are located here.

And based on this, you will also be you will be able to pick up and identify that what type of moment has occurred along this one. So, this fault geologically, we understand that this is a right lateral fault. And what we see based on the now or observe considering the arrival of the seismic waves, so, fault seismic stations are put with respect to the fault line here and during an earthquake and the first arrival wave this what is shown is the positive one and this 1z is also positive one on the side. So, this shows push away from epicenter.

So, this is been pushed away this area has been pushed away from the epicenter of the epicenter here for example, and this also pushed away from the epicenter and various this 1 is the negative, so this pulls towards the epicenter. So, you have the pulling towards one another and these 2 blocks are pushing away from one another. So the first motion of the P wave arrives and a seismographic station is used to determine the orientation of the fault plane and the direction of slip.

The case shown here is for the rupture of right lateral strike-slip so you are having a right lateral strike slip, note that the alternative pattern of pushes and pulls would remain the same. So this remains the same if the plane perpendicular to the rupture with left lateral displacement has been taken into consideration. So seismologists can usually choose between the 2 possibilities using additional information such as field mapping of fault trace.

So, what we are trying to tell you here, this one are you consider this one here then the motion remains the same here because what has been recorded, but based on the along with the psychological information, the field information is extremely important. Now, this type of exercise helps us.

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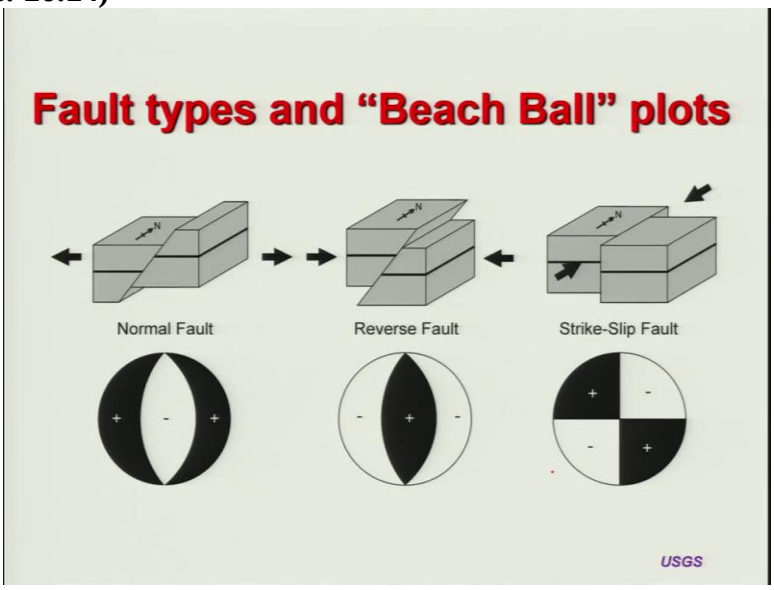

In identifying the fall times that is what we call the either it is reverse fault normal fault and the diagram which we get has been termed as Beach ball diagram. So, we have in case of the normal faulting, you will find which has been shown that you have the 1 block is moving away. So,

there is an extension here and this shows the compression here this in the case of the worst fault, whereas this in this case you have compression here you have the extension along this one. So I will stop here and we will continue on the next picture. Thank you so much.