Earthquake Geology: A Tool for Seismic Hazard Assessment
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Lecture - 19
Earthquakes in Interplate and Intraplate Regions

Welcome back. So in previous lecture where we discussed mostly about the seismic waves and why seismic wave understanding is important for the hazard, seismic hazard in particular. So we looked on different types of seismic waves, body wave, surface wave and their direction of propagation and their behavior and of course we also discussed about the velocities.

And whether the seismic waves in particular body waves will be able to travel through different medium then how they will behave and also we at the end we had some discussion on the frequency of the seismic waves and their implications towards the amplification of the earth surface depending on the geology of the particular sight of interest.

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Now there is another significant topic which we would like to you to have understanding is related to the interplate, intraplate and stable continental region earthquakes. So practically in India we see mostly the interplate and the intraplate earthquake and also to some extent what the region which has been classified at a stable continental region also exist. So we have all 3 in total.

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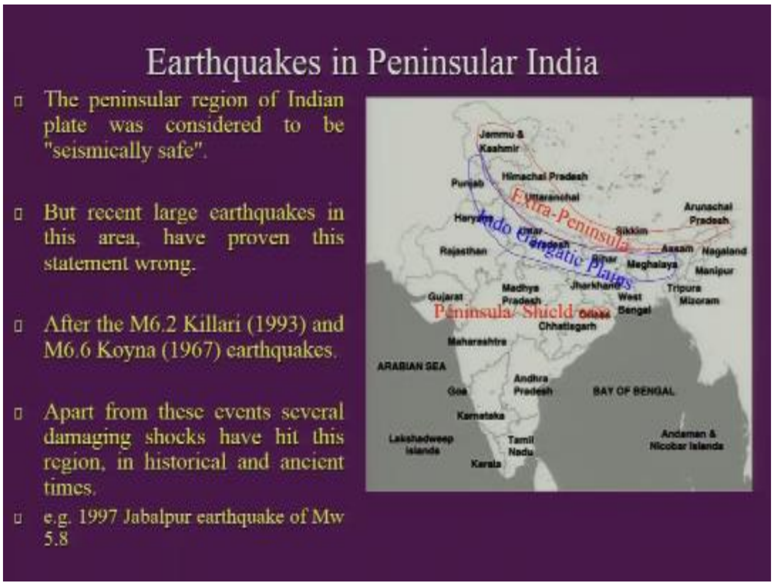

So if you just look at the physiographic divisions of India then what we have is broadly we can divide into 3. So we have the extra-peninsular area then we have the Indo-Gangetic Plain and then we have peninsula shield area. Now before 2000 this Latur earthquake and this area whole area was been considered as a most stable region, but this was proven wrong after experiencing the 19 if I am not wrong this was 1993 Latur earthquake or Killari earthquake.

So peninsular region of India, Indian plate was considered to be seismically safe. So the (()) (02:38) area that what we comprise of mainly the cratonic rocks was considered to be the most safest one excluding this power portion of Kutch because we had a couple of earthquakes in this region which were damaging and also those earthquake resulted into a drastic changes in geomorphology.

So landscape changes was evident during those earthquake. So with this understanding the recent large earthquakes in this region have proven this statement wrong and that was after magnitude 6.2 Killari earthquake or Latur earthquake and 6.6 Koyna of course the Koyna earthquake was your reservoir induced seismicity related to the reservoir induced seismicity, but this earthquake that is Latur or Killari earthquake in 1993 is considered to be because of the ongoing deformation.

Apart from this events several damaging shocks have hit this region in historical and ancient time. So when we looked at the scientific groups looked at the historical data then they found that this was not the only earthquake that is the Killari earthquake which shuck the region in this area, but there were many more shocks or the earthquake which were recorded during ancient time.

And then another one was 1997 Jabalpur earthquake which took place somewhere in this region that is in Madhya Pradesh area which again has alarmed that the area which was considered to be the most stable there is no more earth to be considered as stable and that also was one of the region which was incorporated in the seismic zonation map.

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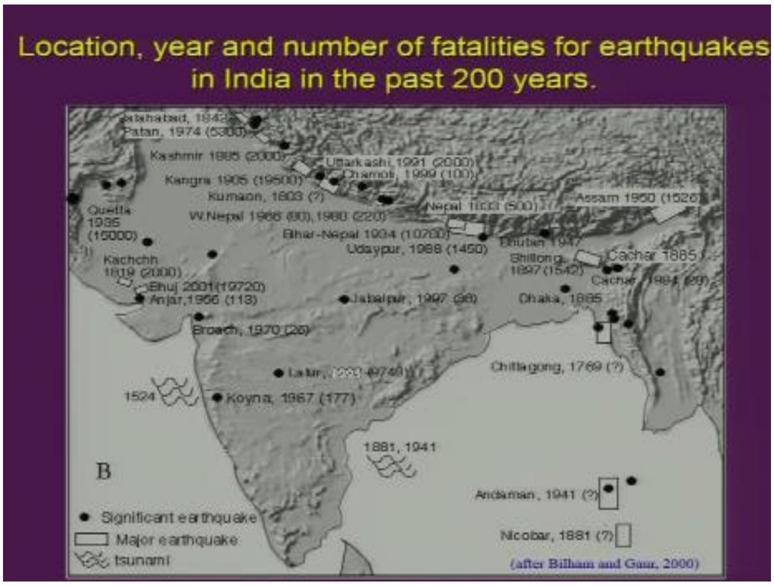

So with this, this part which we discussed in the previous one also so there is a correction here there is about the Latur Killari earthquake 1993 instead of 1992, but rest has been (()) (05:00) and again as I told in the previous lecture also that this map was published in 2000 so we do not have the inclusion of the earthquakes which have occurred like 2004 along this one and we do not have the inclusion of 2005 earthquake Muzaffarabad, Kashmir earthquake and then two more earthquakes in this region that is about 7.5 that is in Nepal 2015.

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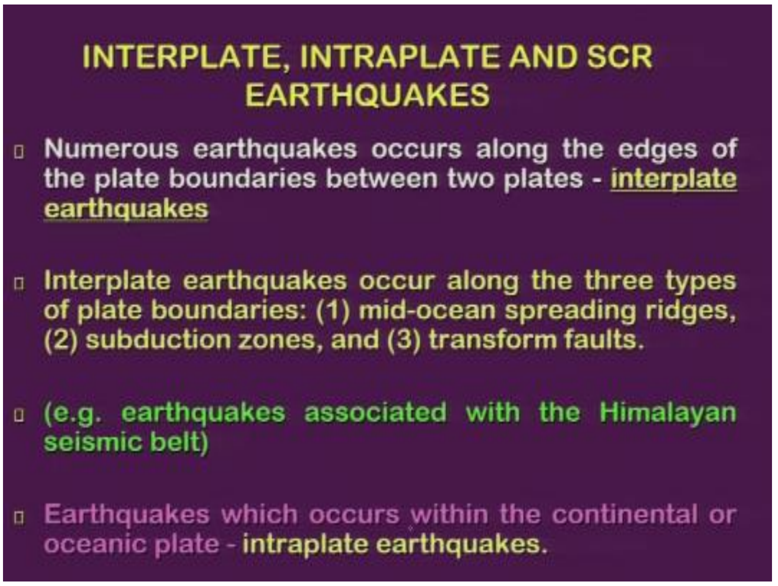

So interplate, intraplate and SCR earthquakes. So if you look at into the details a very simple classification that numerous earthquake occurs along the edge of the plate boundaries between the two plates and those are termed as interplate earthquakes. So mainly such boundaries if we take then we have mostly along the mid oceanic spreading centers then we have along the subduction zones and we along the transform zones.

So these are all the earthquakes which are aligned or concentrated along this type of plate boundaries are termed as interplate earthquakes. For example, earthquake associated with Himalayan seismic belt and even you can consider this along the subduction zone that is Sumitra-Andaman subduction zone. So these are all considered to be the earthquakes which are occurring in interplate region.

Earthquakes which occur within the continents all oceanic plates are termed as intraplate earthquake. So any earthquake which occurs within the plate away from the plate boundaries are termed as intraplate earthquakes.

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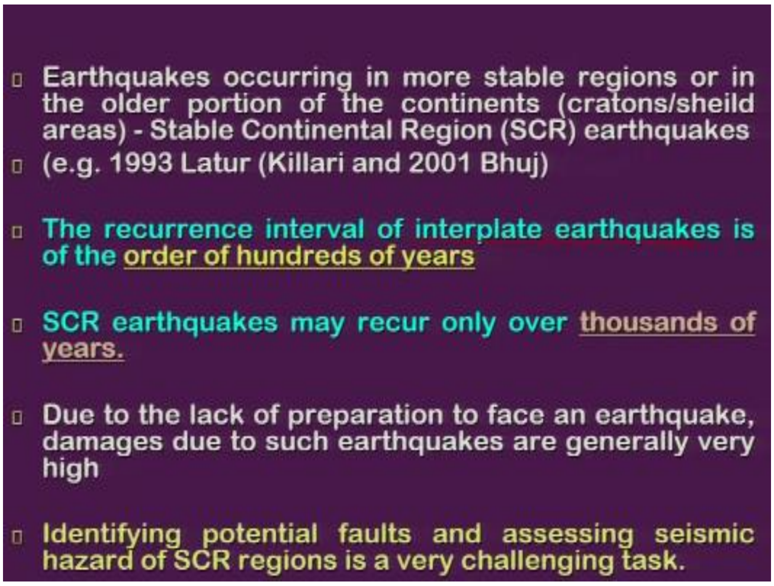

Now earthquake occurring in more stable region or in the older portion of the continents similar to what we have been talking about the shield areas the peninsular India then those type of earthquakes are considered to be or categorized the earthquake occurring in stable continental region. So example is your 1993 Latur or Killari earthquake and 2001 Bhuj earthquake.

Now here for us the portion which we should emphasize upon is not the interplate and the intraplate earthquake the reoccurrence interval along in this region mainly. So in case of if you remember that we had we discussed about the deformation, rate of deformation the convergence rate between the Indian plate and the point in Eurasian Plate that is in Tibet that the convergence is almost like 50 millimeter or so.

And out of that 50 millimeter hardly 5 millimeter has been consumed by the rest of the plate whereas 20 to 21 millimeter is taken up by the collision zone which is marked between the Indo-Gangetic Plain and the Himalayas. So the reoccurrence interval in the intraplate case is at the order of 100s of years and as have been emphasizing in few of my lectures not this reoccurrence interval in Himalaya is around 500 to 600 years or almost 700 years.

Now about the SCR earthquake they may require only over 1000s of years of the reoccurrence interval is much larger and this can be directly compared with the conversion rate that is what we have in the difference along the that is along the Himalayas across the Himalaya we are having around 20 to 21 millimeter and the rest of the plate is having around hardly 5 millimeter.

So the reoccurrence increases or reoccurrence is much larger as compared to what we see in the interplate earthquake and in SCR it will be more than like 1000s of years. Now due to lack of preparation to face an earthquake damage due to such earthquake are generally very, very high and this is in case SCR earthquakes because the time interval between the two earthquakes large magnitude earthquakes will be more than like 1000 years.

And this I would like to emphasize here that our studies from the Gujarat region have revealed that the reoccurrence interval along the active fault in Kutch is more than 2,000 years. So the memory of human memory is very short and if the earthquake is not required in a shorter period then we lack in preparation because we consider that this area is quite stable and no earthquake has been experience or recorded from this region.

So identifying potential faults and assessing seismic hazard of SCR region is very challenging task. So again this can be this point can be justified based on that if you are having the larger reoccurrence interval so the landform which was been formed or modified because of the tectonic activity that is what we call the rupture may get eroded and will not be will preserved on the surface.

Hence, it makes a difficult task to identify such weak zones or the manifestation of the ongoing deformation. So for example it is comparatively easy to identify the tectonically active landforms in Himalayas as compared to what we do study in Kutch region because the recurrence is so high that the features are not getting preserved on the surface because of the erosion.

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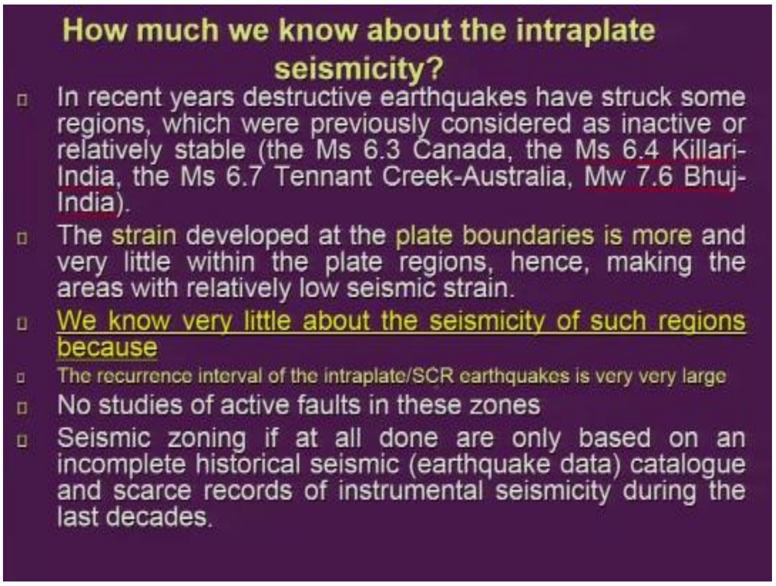

So how much we know about the intraplate seismicity? In recent years' destructive earthquakes have struck some regions which were previously considered as inactive or relatively stable. So example is not only from Gujarat or Maharashtra, but even from the areas like Canada and Australia. So these are the 2 events which occurred in what we considered as a stable continental regions from India.

So Killari, Latur earthquake and Bhuj earthquake with magnitude 7.6 and Killari was 6.4. Now the strain developed at the plate boundary is more and very little within the plate region. So what we had discussion that we have if we consider this Indian plate here then along the plate boundary across this one it was around 20 millimeter per year and rest of the portion which was consuming was around 5 millimeter.

And that was out of (()) (13:28) what we looking at 50 millimeter per year. So of course out of this half is being getting consumed by along within the Indian plate portion and risk goes with the area in the Tibetan side or China side. So if you just keep this in mind that is your 5 millimeter and you have 20 millimeter than the strain which is going to develop in this particular region the strain will be much, much higher.

So higher strain along the Himalayas as well as this region will have low strain. Now this has direct implication with the recurrence intervals. So in the area (()) (14:33) strain will have shorter recurrence and the areas with the low strain will have longer recurrence. So this you can remember and this will help you in understanding that what will be the scenario of occurrence of earthquake in this 3 regions.

So this is Himalayan rest of the area so the strain developed at the plate boundary is more and very little within the plate region. Hence, making the areas with relatively low seismic strain. So this region will be low seismic strain region that is your the rest of the Indian plate. So of course we know little about the earthquake occurrence in the stable continental regions because the recurrence is very large.

And the earthquake signatures which are been preserved on the surface are very weaker and that is a different task okay, but we have different methods to look at the signatures that is in the secondary effect like (()) (16:09) and that we will discuss later on. So we know very little about the seismicity of such regions because the recurrence interval of the intraplate SCR earthquake is very, very large.

No studies of active faults, but I would say that now we can say that few studies have been carried out from this region mainly the SCR or intraplate region in particularly in the area where we had 7.6 earthquake. So very few studies have been carried out because the hazard in terms of is not alarming in very short time. Hence, we keep avoiding this region so these are the reason of less priority.

So seismic zoning if at all done only based of on a incomplete historical seismic records or the catalogue and (()) (17:10) records of instrumental seismicity during last decade. So this again was the case and the lesson which we learn from Bhuj earthquake that we were not at all prepared for this event as well as this event in the SCR region or the intra plate region and that is because of the very long recurrence interval.

And no active fault studies were being carried out. So we never had an complete understanding of what how the tectonic deformation will eventually result into the future earthquakes and also the incomplete historical records in that in those regions only from Bhuj area what we had was the 2018-2019 earthquake and another was 1956. So this were the two only earthquakes which were the damaging earthquakes from this region what is being classified as intraplate and seismic stable continental regions.

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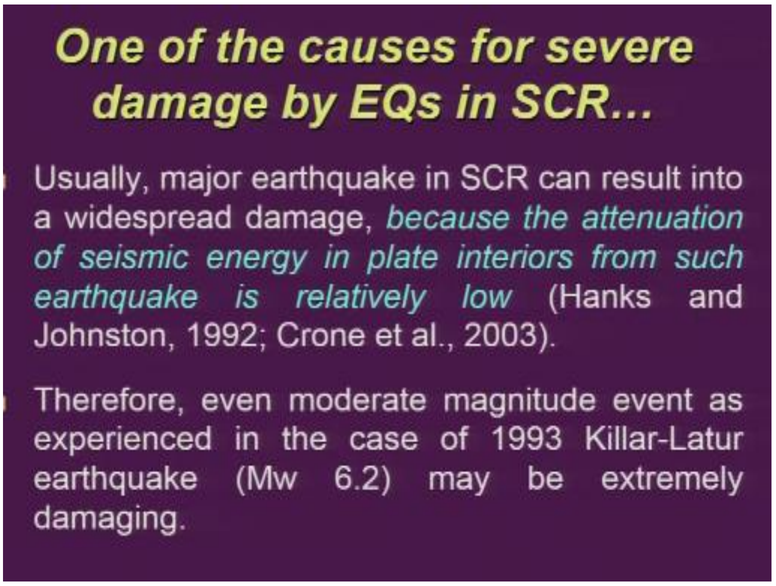

One of the causes for severe damage by earthquake in SCR region which we discussed in the previous slide is that very long recurrence interval is one and then another one was that the preservation of such tectonically generated features like faults scarps and displaced landforms are very weaker because we will be eroded very fast because the time interval is very large between the two events.

So usually major earthquake in SCR region can result into a widespread damage because the attenuation this is another very significant reason for that because the seismic energy in the plate interior from such earthquake is relatively low. So if the energy is not getting attenuated in such regions then they will result into the more damage in the region. Therefore, even moderate earthquakes that is moderate magnitude earthquakes as experienced in the case of 1993 Killari or Latur earthquake maybe extremely dangerous.

And we of course we knew that more than 9,000 lives have been people were got killed during the Latur earthquake and with a moderate magnitude or magnitude was 6.2 only and the reason is because the attenuation of the seismic energy in such regions by such earthquake is relatively low. So it never get attenuated very fast.

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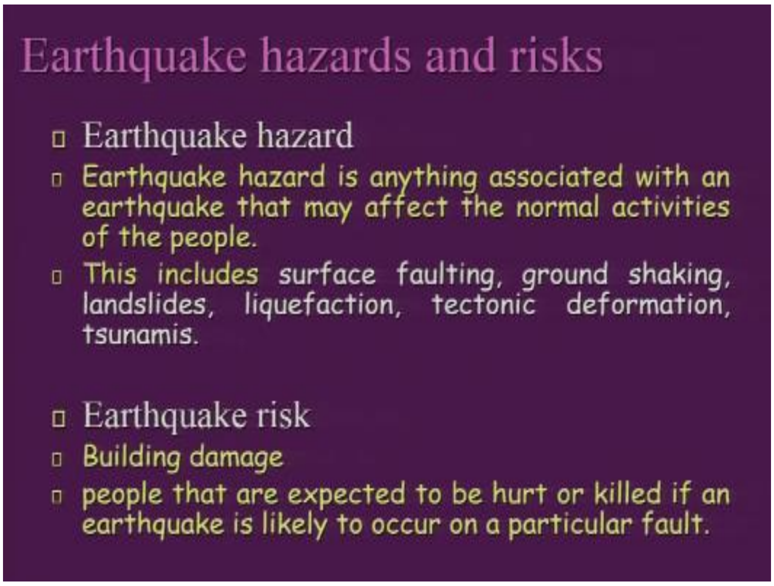

So earthquake hazard and risk usually what we consider as earth hazard is anything associated with an earthquake that may affect the normal activities of the people this includes surface faulting, ground shaking, landslide, liquefaction, tectonic deformation and tsunamis. Tsunamis are of course on land sides and what we call the surface shaking, liquefaction these are all associated secondary features.

Or secondary phenomena which will be always experienced during the earthquake then earthquake risk of course it comes (()) (20:57) earthquake never kill people by building doom and this is because of the poor construction even have maximum building damage and people that are expected to be hurt. So the risk part will be based on that. So what will be the number of buildings which are (()) (21:20) to the earthquake, shaking ground shaking.

And how many people the population is likely to be getting affected or hurt or killed during A particular earthquake. Of course if you talk in terms of the groups or the research groups who are talking about the geotechnical aspect then the definition usually slightly varies, but they talk in terms of that what is the potential and the probability of earthquake at a particular given location.

So but as a geologist if we consider then for us this is the difference between the major difference between or the fundamental difference between the earthquake hazard and risk, but in geotechnical part we take into consideration the source of the earthquake then what is the magnitude of the earthquake, expected earthquake, probability of that earthquake that is again the recurrence interval and the geology of the sight of interest okay where it is located.

So this all parameters we will talk about the deterministic seismic hazard and probabilistic seismic hazard. We are not going to get into the detail of that about the probabilistic and deterministic, but I will try if I can give you some slides on that at a later stage.

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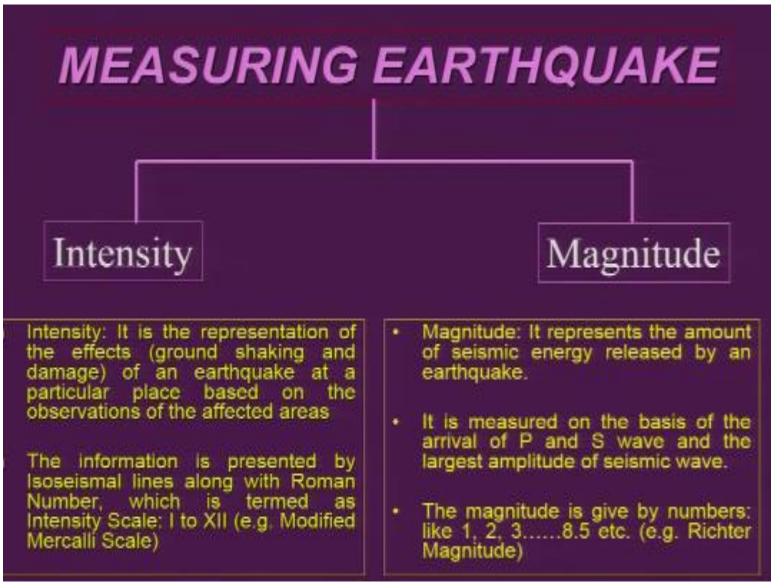

Now measuring earthquake as we have we started with the understanding of seismic waves and in the frequency of seismic wave and interplate and intraplate earthquakes and the high strain area, low strain area and the recurrence interval. So the measuring earthquake is another important aspect to we should know before we get into the details of the methodology of (()) (23:24) how we are going to carry out.

And how we are going to identify the related tectonically develop landforms. Now measuring earthquake is usually done based on the intensity one where the intensity is with presentation of effects ground shaking and damage of an earthquake at a particular place based on the observation of the affected area. This information is presented by isoseismal lines along with the roman letter numbers which is termed as intensity scale.

And it can range from 1 to 12 whereas the magnitude is it represents the amount of seismic energy released by an earthquake. It is measured on the basis of the arrival time of P and S wave and the largest amplitude of the seismic wave. So in other than the P and S wave seismologist also uses the surface waves to calculate the magnitude and the magnitudes are usually represented by the numbers that is 1, 2, 3 etcetera on (()) (24:51) magnitude.

Whereas the intensity has been done on the modified mercalli scale. So this is the major difference between the intensity and the magnitude. So in earlier time when before the invent of the instruments measuring the magnitude and earthquake of measuring the earthquake mainly. So intensity was very important and but still even though we have the instruments installed and they are recording the earthquake occurrence of the earthquakes.

We do the analysis or we do the we keep collecting the observations after any earthquake that is based on the damage pattern and the deformation in that particular area and prepare the intensity map which are known isoseiesmal maps.

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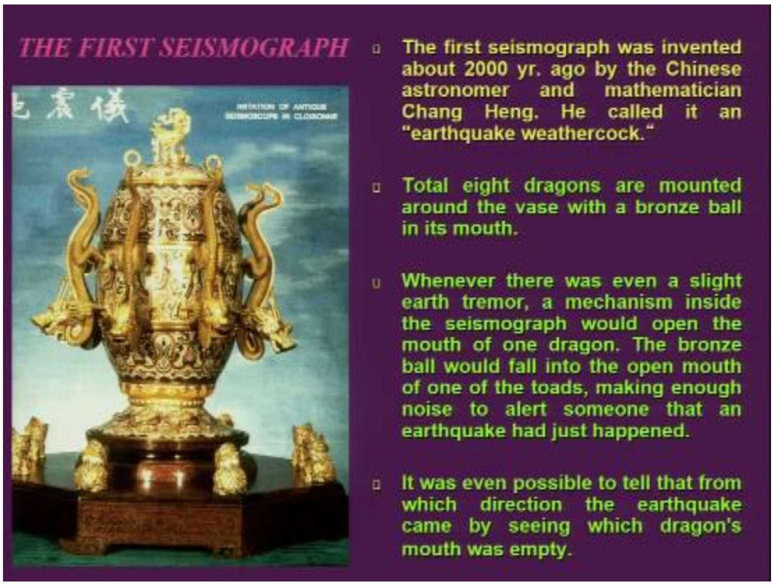

Now if you back into the history of the seismograph so it takes you as back as almost like 2000 years ago. So the first seismograph was invented about 2000 years ago by Chinese astronomer and mathematician Chang Heng he called this device as a earthquake weathercock. Now this is based on very simple physics that it has like total 8 dragons are mounted around the vase with a bronze ball in its mouth.

So you have the dragon and it has like 8 dragons which we can see only 4 and 4 are on the back side. So all this dragons 8 dragons are holding bronze ball in their mouth. So whenever there was a even a slight earthquake earth trimmer and mechanism inside the 8 so what you have is one is the dragons here 8 dragons and respectively you have toads with open mouth which are also lying and sitting exactly below the open mouth of the dragon here.

So even with the small tremor a mechanism inside the seismograph could open the mouth of one dragon and the bronze ball would fall into the open mouth of the toads. So you have this making enough noise to alert someone that earthquake had just happened. So this was even with this even it was possible to tell that from which direction the earthquake came that is the seismic wave came and by seeing which dragons mouth was empty.

So this was the earthquake weathercock which was invented way back in 2000 years ago by Chinese astronomer and mathematician.

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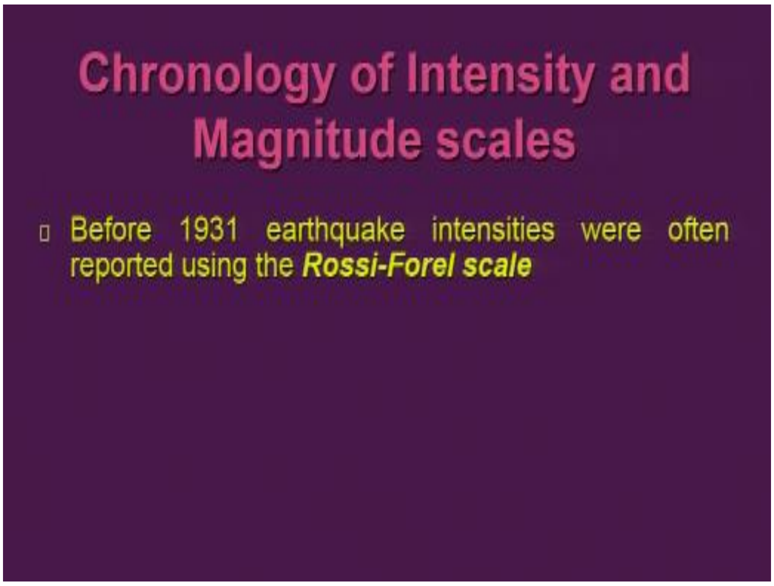

Now if we look at the chronology because as we discussed in one of the lectures that with no data and what we learn from different earthquakes we keep improving our methodology and we keep improving the methods which help in interpretations and all that. So the intensity scale as well as the magnitude scale kept on revising based on the input of the data and what lesson we learn from respective earthquakes. So anyway what we can do is I will stop here and we will start with the chronology of the intensity and the magnitude scales in next lecture. Thank you so much.