Earthquake Geology: A Tool for Seismic Hazard Assessment
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Lecture - 20
Earthquake Magnitude and Intensity Scales (Part-1)

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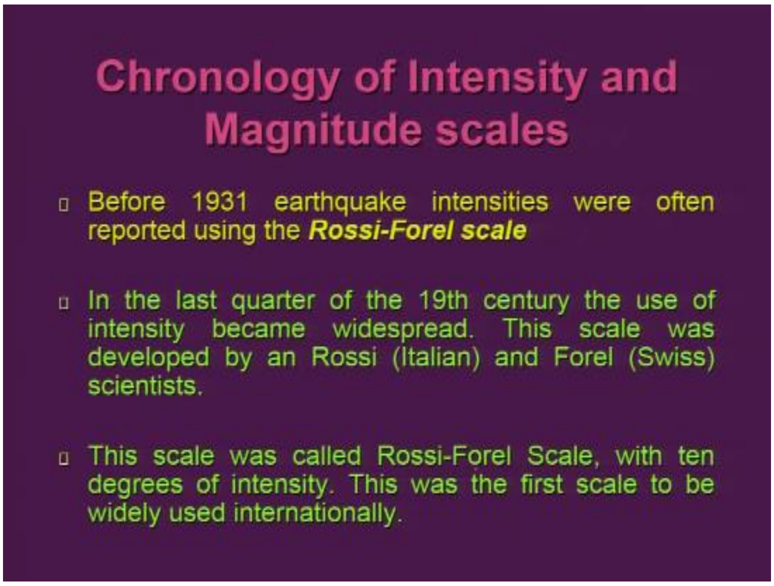

Welcome back. So let us now have brief understanding about the intensity and the magnitude scale and how this two scales have evolved over the time. So if we take the chronology of the intensity scale then in before 1931 earthquake intensities were often reported using Rossi-Forel scale and in the last quarter of 19^{th} century the use of intensity scale become widespread.

And this scale was developed by Rossi and Forel the 2 scientists from Italy and Switzerland respectively and this scale was called Rossi-Forel scale with 10 degree of intensity. So we have like from roman letters if we take 1 to 12 so initially the Rossi-Forel scale was being given with 10 degree at 1 to 10 and this was the first scale to be used widely internationally. Now the intensity scale mostly if you recall the first slide of the previous lecture.

Or the first slide of the intensity in the magnitude lecture and you can recall that particularly the intensity depends on the damage pattern. So whether this should be considered the same for the different region that remains a question.

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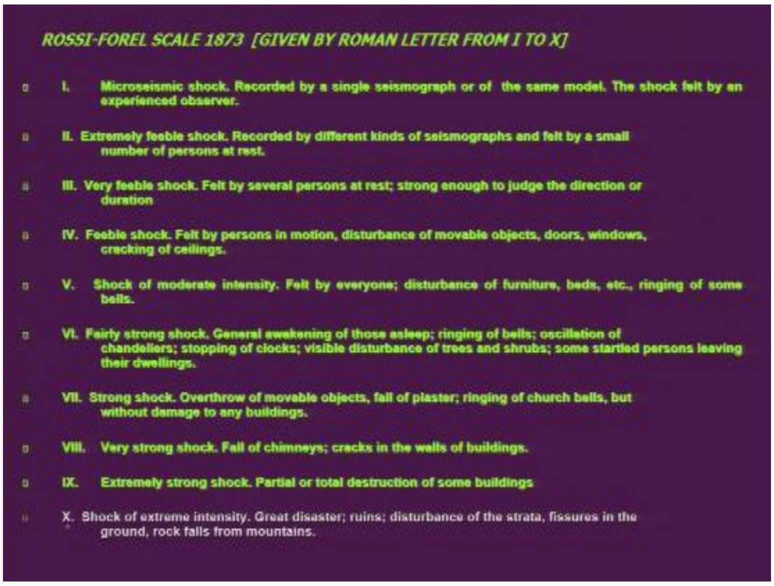

So Rossi-Forel scale was given by roman letters from 1 to 10 and they were been like classified as been given here. I would like to emphasize here that it will be difficult for you to remember, but at least you can refer to the scale which has been given like the one intensity means what actually microseismic shock recorded by single seismograph or by of the same model the shock felt by an inexperience observer.

So you may not all people in that region will be able to experience this minor shock so microseismic then we have extremely feeble shock recorded by different kinds of seismograph and felt by small numbers of persons at rest then very feeble and so on. So you have like up to 10 which has been given and from 7 you can see that it was strong shock or overthrow the movable object, fall of plaster, ringing of church bells.

But without damage of any buildings and then so on and finally you have the 10 shock of extreme intensity, great disaster, ruin now there is a building, collapsing of the buildings, distribution, disturbance of the strata that is in the sediment stratigraphy, you have development of fissures in ground, rock falls from mountain. So this was the classification which was been given by the Rossi-Forel scale of intensity scale. So based on this and the damage pattern and the ground formation one can classify that what was the intensity in a given side by a particular earthquake.

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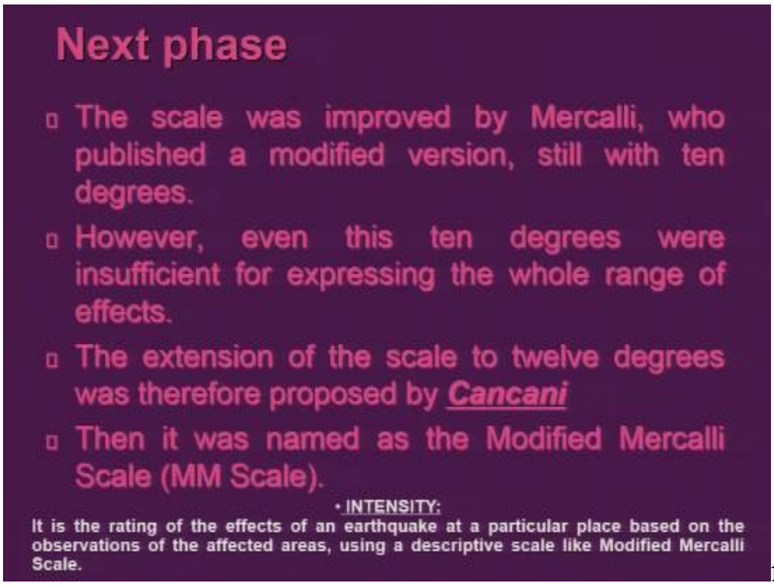

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Further the next phase this scale was improved by Mercalli who published a modified version still with the 10 degrees. However, even this 10 degree were insufficient to express the whole range of effects and effects here we are talking about the damage pattern and ground deformation. So this was still difficult to express the overall affect by any particular earthquake.

The extension of the scale to 12 degrees was therefore proposed by Cancani and this was after the Mercalli and this was been termed as Modified Mercalli Scale and usually you will find in literature that this has been given the intensity has been given in MM this stands for Modified Mercalli Scale. So this was Modified Mercalli Scale was with 12 degrees and that was done to express the wide range of damage or the effect by any particular earthquake.

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So Modified Mercalli Intensity Scale if we take the maximum so you have the intensity here which is from 1 to 2 felt by very few people really noticeable similar to what we were looking at the Rossi-Forel one. Now then comes the third one is you felt indoor especially on upper floors and this is because of the different buildings will behave differently that is the shorter ones and the taller ones.

And the object where it has no damage will be experienced if the intensity is free and then so on we have 4 to 5 felt by many people, 6 to 7 some structural damage, buildings will be there, cracks involves and high rise structures like building and chimney will experience the cracks. Then 7 to 8 felt by everyone difficult to stand some heavy furniture moved, some plaster falls, cracks involves are formed and slight damage to high rise buildings and chimneys.

Then coming to 9 and 10 major damage collapse of weak buildings and cracks to the stronger buildings. Then coming to 11 to 12 total damage or nearly total damage. Now very few points if you look at here that this scales usually talks about that chimneys and in some places the ringing of bells and all that of church. So depending on what type of construction we have in a particular region this will keep varying from place to place.

But mostly we use the Modified Mercalli Scale to identify the damage related to the earthquake. So the isoseismal maps are very much similar what we see in the contour maps on topo sheets. Now considering the intensity scale and the pattern of damage and the deformation in particular region the intensities are being assigned.

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For example, if you consider this map from US then you have like the epicenter is here. So this region experienced the intensity of 8. So mostly you will you will not find on this such maps this numbers, but usually it has been denoted by the roman letters. So what we can infer is that there was strong ground shaping and much comparatively higher damage as compared to the areas which are sitting little far away from the epicenter.

So this was a 8 and this whole region based on the damage pattern has been classified at this had an intensity of 7 and then some locations were having 6 also. So this whole region is sitting in 6 then goes and will have lesser intensity (()) (09:30), but if you look at the map here then we have the 8 intensity here, but this region was having comparatively higher intensity even other than the epicenter area.

Now this was this probably was because of the local side effect because the material within the earth crust will behave differently and you can recall the part which we discussed in the amplification part. So this probably this region had and very soft deposits or alluvium which must have resulted into the higher amplification and strong ground shaking as compared to even the epicentral area where maximum amount of energy was released during an earthquake. So such lines or the contours which are been generated by connecting the similar pattern of damage or effect will give you the isoseismal map.

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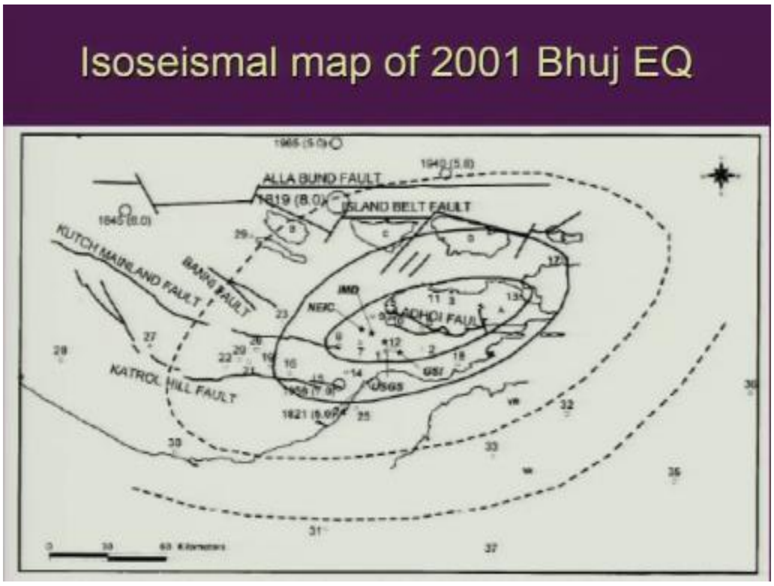

This is from 2001 Bhuj earthquake so the earthquake was in this region and as you move away then the damage pattern is less or the damage is less and the damage pattern varies from the epicentral area and the areas which are sitting away from that. So this was an isoseismal map of 2,000 Bhuj earthquake.

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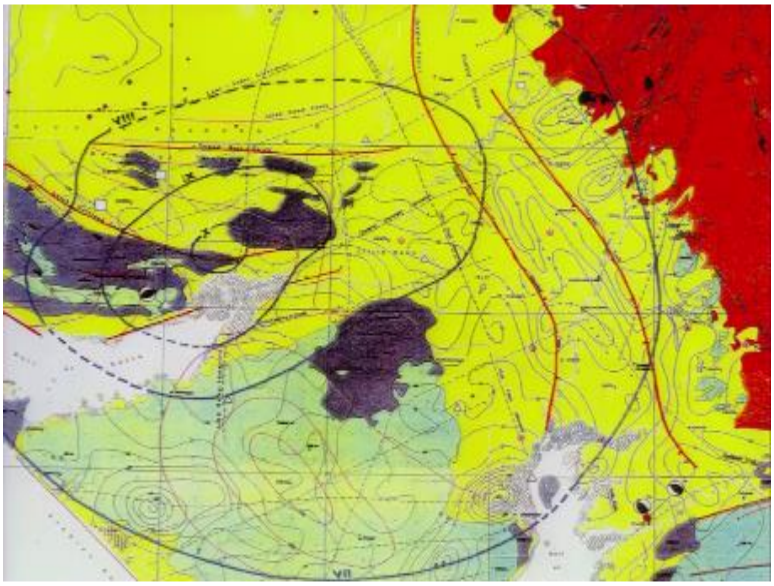

Another one has been given here and where the intensity has been plotted on the geological map. So if you see here then what we have that this region which is marked as yellow is all alluvium. So you have the softer deposits here hence the intensity was much comparatively higher. So this region was having the intensity of 8, this was having 9 and this region where the earthquake was trigger at an intensity of 10.

And further you move you have 7 here. So you have 10 then you have getting lesser and here you are having 8 we are having 7 here. So even the areas which were sitting if you consider this one somewhere over here is Ahmadabad which is sitting almost like 300 kilometers from the epicentral area was also affected and what we learn that some pockets in this region that is the area comprising the alluvial plain of Gujarat experienced strong ground shaking.

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Figure 3. Macroseismic distribution for the 8 October 2005 Kashmir earthquake in the backdrop of topography and tectonic elements of the region. KBT, Kashmir Boundary Thrust; MBT, Main Boundary Thrust; MFT, Main Frontal Thrust. (Inset shows the contours of high intensity isoseismals obtained by present approach (blue color) with those prepared by GSI (Source: http://www.gsi.gov.in/pokeq/pokeq.htm).

This was the case in 2005 Muzaffarabad earthquake where the seismic shaking was experienced right up to Amritsar and in the Indo-Gangetic Plain far away from the epicentral area in this region. So the intensity was almost like 4 here and 5 near the Northwest Himalaya that is in Amritsar, Gurdaspur and Jalandhar region and even in the Kangra region in the lesser Himalayan zone.

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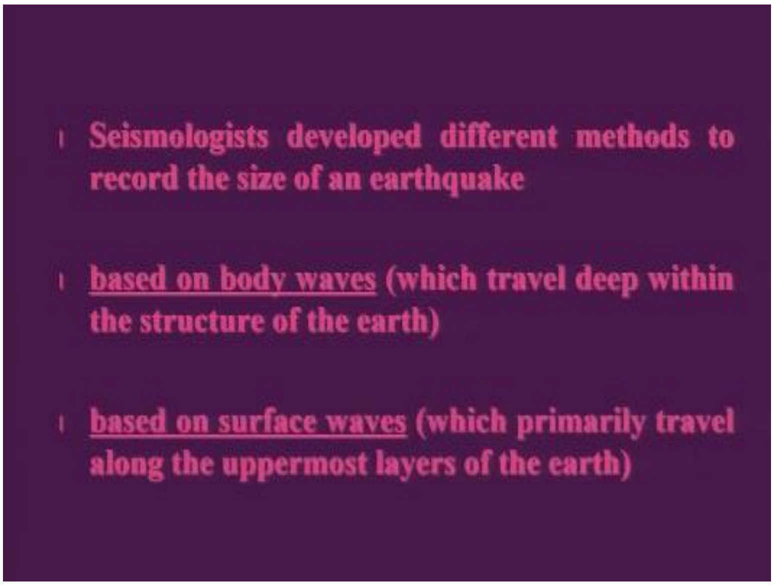

So seismologist developed different methods to record the size of an earthquake based on body wave which travels deep within the earth structure and then secondly based on the surface wave which primarily travel along the uppermost layer of the earth crust. So based on this seismologist have developed different magnitude scale to record and particular size of earthquake.

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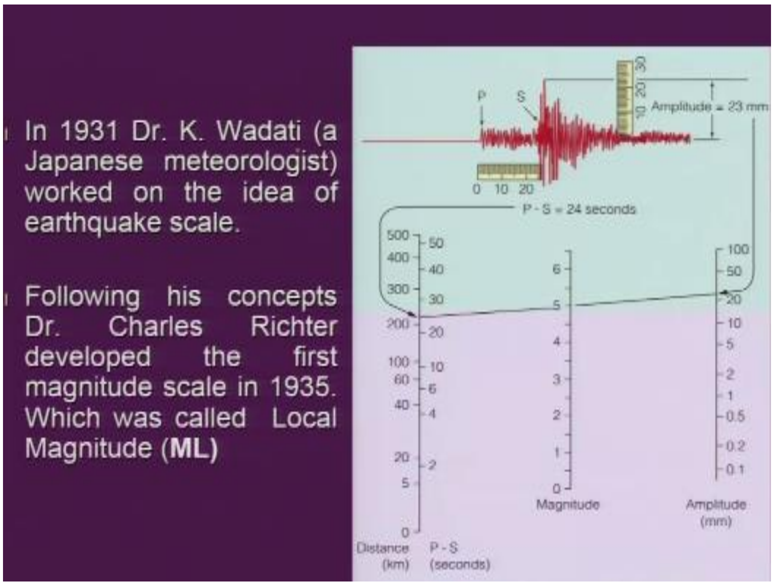

So this part we discussed in the previous one that we use mostly the arrival of P wave and S wave and the maximum amplitude of a particular seismic wave to identify the magnitude of an earthquake. So this was in 1931 Wadati a Japanese meteorologist who work on the idea of earthquake scale follows his concepts Dr. Richter developed the first magnitude scale in 1934, 1935 and this scale was termed as local magnitude scale ML it has been denoted as ML local magnitude scale which was been modified and the proposed by Richter in 1935 after the concept which was being given by Wadati.

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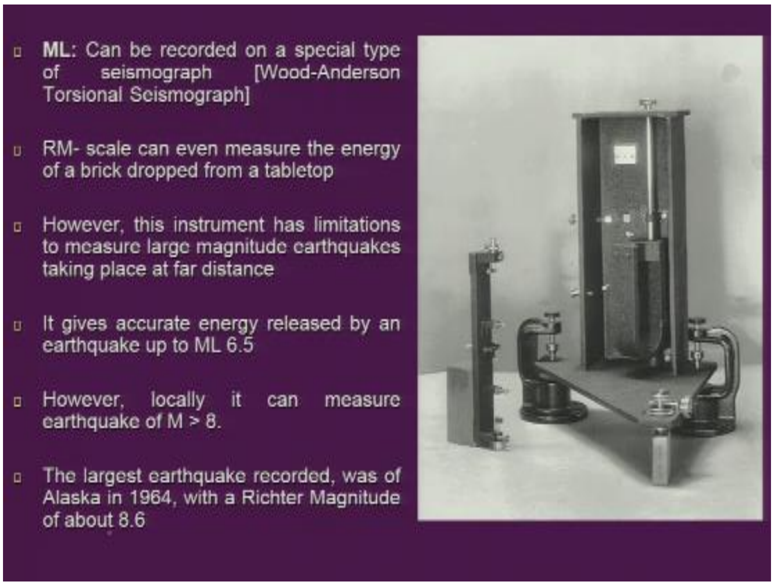

Now the scales again as in what we have looked at the chronology of the intensity starting from Rossi-Forel and Modified Mercalli Scale, Mercalli scale and then Modified Mecalli Scale and similar way with more information and with the lessons which were being learnt during some earthquakes in the past the magnitude scale also got modified over the time. So

ML had like Mercalli local magnitude scale.

Whereas the Richter scale had a limitation which can be only recorded by special type of seismograph and this seismograph has been named as Wood Anderson Torsional Seismograph. So again very much similar to the what we were talking about the seismograph whether seismograph invented by Chinese, but this slightly different mechanism here. So there will be during an earthquake of different frequency waves are being generated.

And this will record the vibrations and will tell us that what was the intensity sorry the energy which was being released. So mostly the Richter magnitude scale can be a was so sensitive that the instrument that it can even tell us that if there is just what amount of energy is being released by even dropping a brick from a tabletop. However, this instrument had limitations to measure the large magnitude earthquakes taking place at far distance.

Now this part if you recall the what we discussed in the different type of frequency of seismic waves generated during an earthquake. So we have low frequency, we have high frequency and the low frequency waves will not attenuate very fast and will travel far distance. So this instrument had limitation to record or measure the distant travelling wave that is teleseismic waves we usually talk about the when we consider mostly the surface waves.

And that will underestimate the magnitude mostly. So the large magnitude earthquakes where we have not been recorded precisely by this instrument and the Richter scale had the limitations. So it gave accurate energy released by an earthquake up to magnitude 6.5. However, locally in the range of around 100 kilometers if this instrument has been placed or has been located form the epicenter.

Then it can measure the earthquake even up to > 8 magnitude, but if this the epicenter is far located and from the instrument then it may undersize the magnitude. So the largest earthquake recorded was Alaskan earthquake 9.64 with a Richter scale of about 8.6. Now if you look at the record of the earthquake this is not exactly the largest earthquake, but this can be classified as a second largest in terms of what we have the records available 9.5 was the largest earthquake of Chile 1960 and this was 9.3 second largest earthquake.

But with the Richter magnitude scale the magnitude which has been assigned was 8.6. So this suggest clearly that this earthquake which was above 9 < 9.5 was undersized. So with this also when you take into consideration this information for the hazard analysis then you may undersize the hazard.

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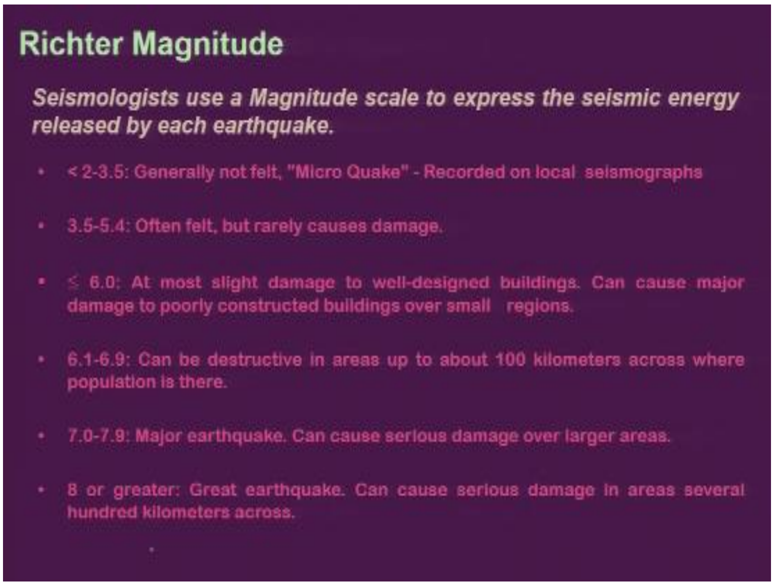

So Richter magnitude seismology to use a magnitude scale to express the seismic energy released by each earthquake. So again very much similar to the intensity scale this has been classified and compared with the intensity scale that if you are having magnitude < 2 because the Richter magnitude and the instrument which was been devised Wood Anderson Torsional Seismograph can record even the drop of the brick.

The energy is released due to the drop in the brick from the tabletop. So from < 2 to 3.5 magnitude generally not felt and they are considered as a micro earthquakes not felt by the people recorded by local seismograph then coming to the next 3.5 to 5.4 often felt, but rarely cost damage <= 6 at most slight damage or to well designed buildings can cause major damage to poorly constructed buildings over small regions.

6.1 to 6.9 can be destructive in areas up to about 100 kilometers from the epicenter across where population is there again this point is important because if you are having less populated area and you may undersize not the magnitude, but you may undersize the intensity that is in terms of intensity scale you may record that damage was not much and not many people got killed during this.

Hence the earthquake magnitude was less or the intensity was less. Hence, ranging from 7 to

7.9 is considered a major earthquake can cause a serious damage over large area 8 or greater than. They are this type of earthquakes are being considered as great earthquake can cause a serious damage, massive damage in the areas for several kilometers across. So you may you can think of this one, but the magnitude of Bhuj earthquake was 7.6 it was a major earthquake in that region.

So the great earthquakes we have the region like Himalayas which can host the great earthquakes and those earthquakes can cause severe damage and covering larger areas. So this is the classification of the Richter magnitude scale.

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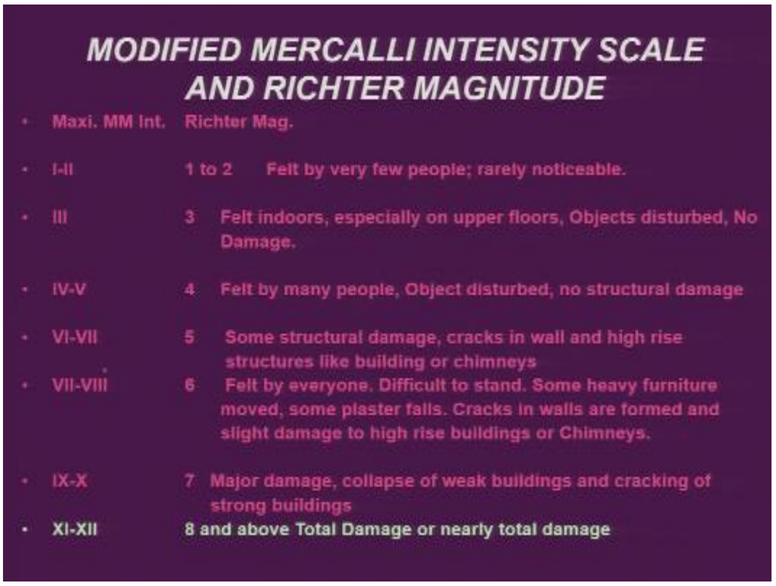

Modified Mercalli Intensity and comparison with the Richter magnitude you have has been given it so please refer it. Okay so you have here you have the magnitude and this is the maximum Modified Mercalli Intensity which has been given. So this goes up to 11 to 12 and this can be compared with 8 magnitude or the great magnitude, the great earthquakes and will result into total damage or nearly total damage.

And hence what we see is the maximum area will get affected and this is the comparison with the intensity scale here. So the comparison between the Modified Mercalli Intensity and the Richter scale.

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So this is an example of seismograph network in Seattle US (()) (23:16) where continuous earthquake are being recorded. So these are all small magnitude earthquakes which are been recorded on the seismograph and as we discussed in one of the lectures that along with the recording of the earthquake that is arrival of P wave and S wave the seismologist and structural engineers will be interested in recording that what as the horizontal displacement and what was the vertical displacement in that particular region.

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So this darker parts what you see is the amplitude of the arrival of seismic waves.

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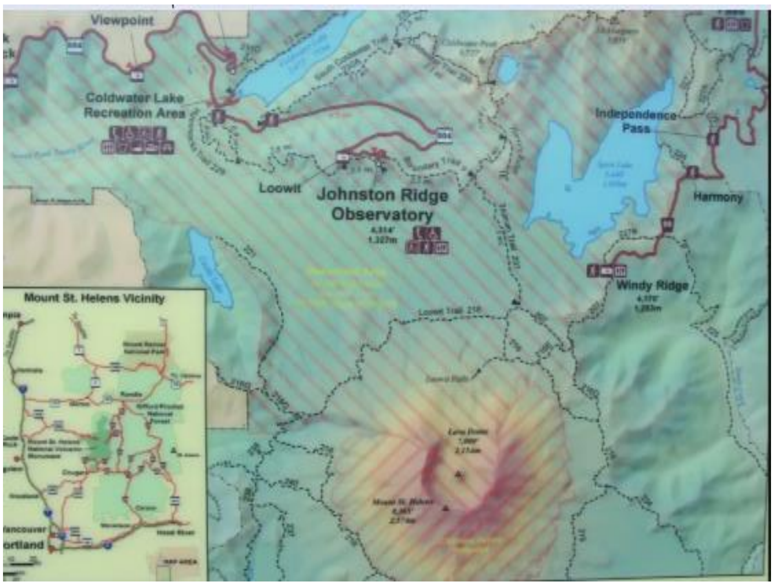

This is an example from the volcanic eruption which was experienced along the Mount Saint Hellensin in US and what they did was they continuously kept monitoring the occurrence of earthquake which was so related to the movement of lava been along the conduit of this cone which was the earthquake were being recorded here.

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So this were the number of earthquakes which we have been recorded just before the volcanic eruption in that region.

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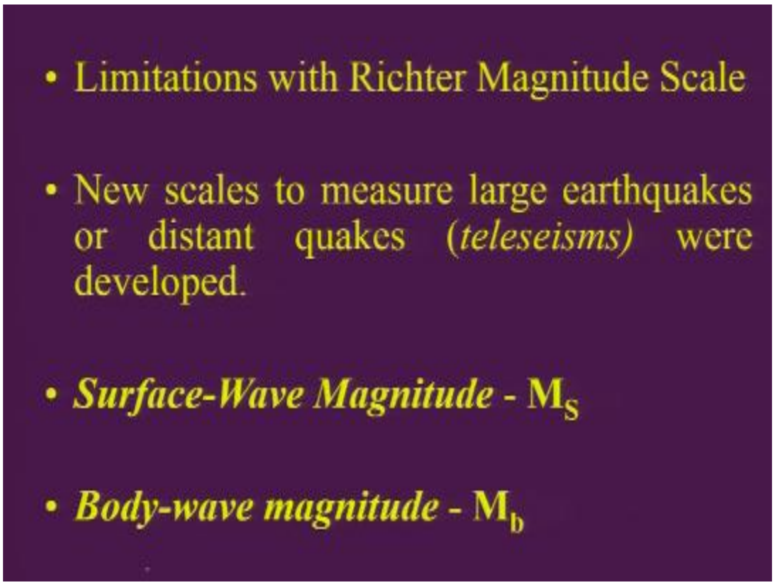

Limitation with the Richter and magnitude scale as we have discussed that the Richter scale can only measure the earthquakes which are occurring in the local area up to 100 kilometers, but the far the earthquakes taking place far away that is a large magnitude earthquakes it has limitations okay. So considering and taking into considerations the limitations new scales to measure large earthquakes or distance earthquake based on the teleseismic waves were developed.

So first it came that let us use the surface wave and with the help of that if we can measure the large magnitude earthquakes and the magnitude scale was being denoted as MS surface wave magnitude and then another one was which came up was the body wave magnitude Mb.

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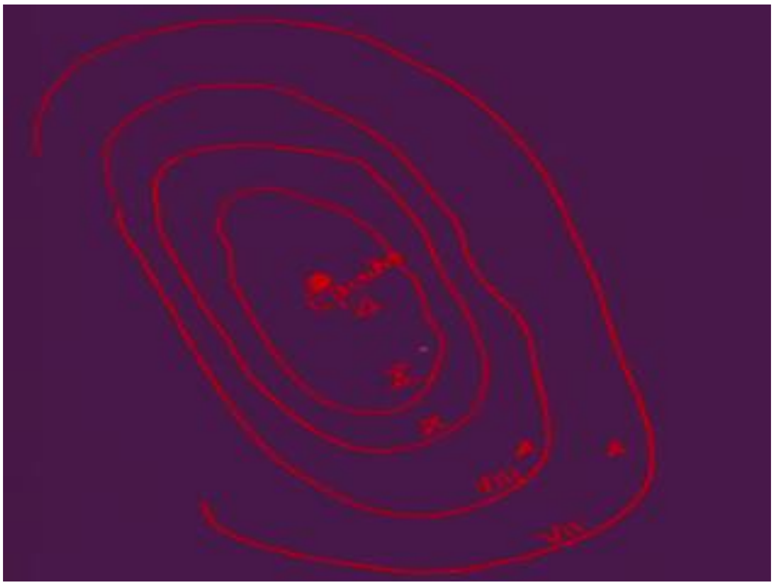

Now before I talk about the difference or the development of the different scale the difference between the intensity like people usually confuse that if the epicenter is here then the intensity will be much larger here than it will further reduce and it goes something like this. So suppose you are having 10 here and then this will might be having like in between you have 9 here and then you are having 8 here and then 7 here for example.

So the intensity reduces and the earthquake which was this in epicenter so this varies from the epicenter area, but in terms of the magnitude, magnitude measured will remain the same as because the seismographs will measure the amount of energy and that magnitude has been assigned based on the arrival of P and S wave. So magnitude the instruments which are located far away from the epicenter okay.

All this instruments will record and give the same magnitude and that will not be like in the case of the intensity because intensity changes that is the seismic shaking will differ, but the magnitude remains the same if we are also sitting far away from the epicentral area. So this part you should keep in mind when we are talking about the intensity scale and the magnitude scale.

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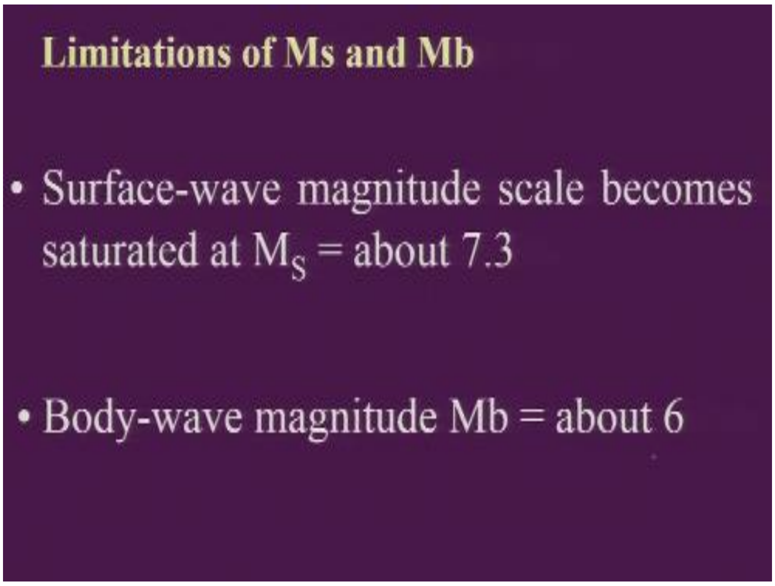

So with the limitation of the surface wave magnitude and body wave magnitude surface wave magnitude scale become saturated at about 7.3 magnitude whereas the body wave magnitude it saturated at about 6 magnitude very much similar to the local magnitude.

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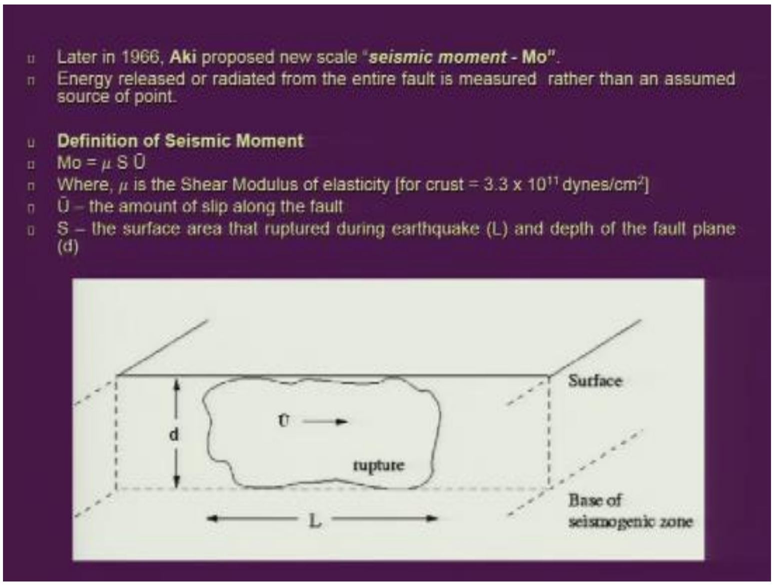

Now with this Aki in 1966 proposed a new scale and that was been termed as moment magnitude. So what he proposed that that the energy released or radiated from entire fault that is a rupture area is to be taken into consideration rather than an assumed source of point. So the seismic moment has been defined as you have as M0 Mo and you have the mu here and the surface and the displacement here.

So mu is the shear modulus of elasticity and for crust is mostly like what we take is 3.2 into 10 to the power 11 times per second centimeter square and U bar is the amount of slip along a particular fault. So what is the amount of slip or the rupture along the rupture the displacement which has been taken and the S is your the surface area that rupture during an earthquake which includes the that is the area so we have the length and the depth.

So the area ruptured and the depth of the fault plain. So this has been taken into consideration to talk about the S. Now with this you can calculate the moment seismic moment and further this information can be quickly used in computing the moment magnitude that has been denoted as MW.

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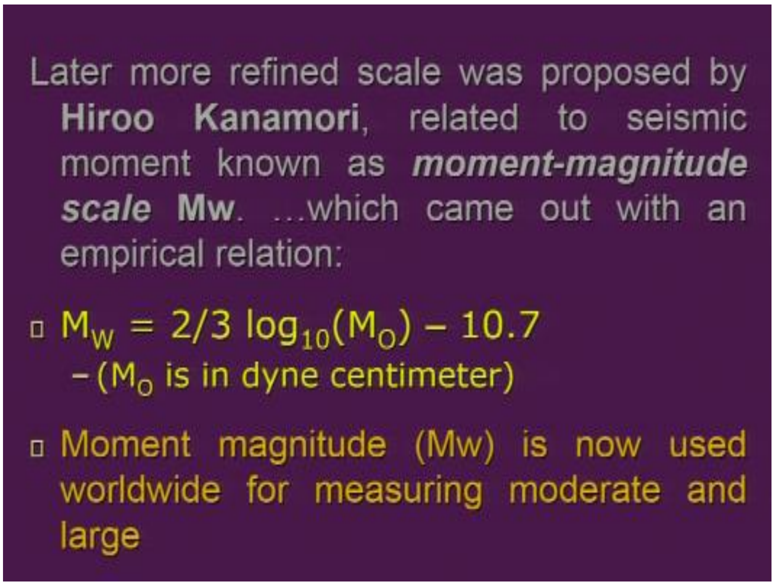

So later more refined scale was proposed by Kanamori related to the seismic moment known as moment magnitude which came out with an empirical relation which is given here and moment magnitude is the scale which is now used worldwide for measuring moderate as well as large earthquake. So with this, I will end my lecture here and will continue with little more details on this in the next lecture and then we will move to the active fault topography part. Thank you so much.