Earthquake Geology: A tool for Seismic Hazard Assessment
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Lecture No 2
Introduction to Earthquake Geology (Part-II)

Welcome back, so in the previous lectures, we talked about the course content and importance of this especially in how we will identify the Paleo earthquakes and which are the regions. So in this lecture, let us move ahead and see what important points we need to understand and we need to learn is most important is.

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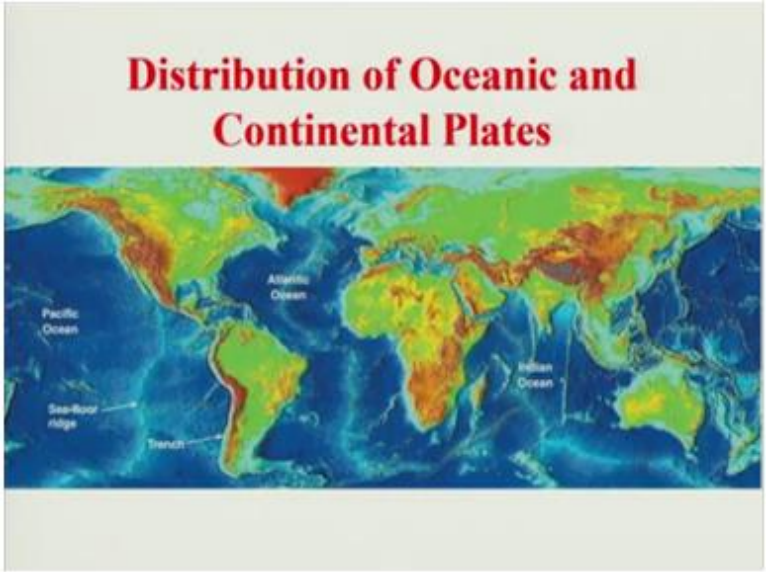

The distribution of Oceanic and continental plates, because these are the regions or the locations which are producing the earthquakes on the Earth's surface or interior. So just on giving an glimpse, of the landscape across the globe we have different plates here and that details we will talk when we are talking about the plate tectonics part but this is what is the configuration of different plates with respect to one another.

So for example we are having the Indian plate, because it is sitting here a very small one as compared to what we are having the African plate and the South American plate earth we can say the North American plate we have a smaller one here and then we have this oranges color or

dark color, features which are the in line forms okay so these are the Himalayas which we are having.

And we have another one is the subduction zone which is existing here and as well as over here also this is a macron zone so distribution of the oceanic plate, so there so these are all oceanic plates what we are having so either they are subjecting with respect to one another. So we have this as continental plate subjected build below the the continental plate, but it now it is colliding but initially it is subjected.

Because we had an ocean plate, in front of and the indian continental plate and for example over here, we have this configuration where the oceanic plate is subjected below the continental plate and these are the the landforms or the mountain chains which have already been developed because of or we can say that this is the manifestation of the deformation between the Nazca plate there is an oceanic plate subducting below the South American plate.

So this all we will discuss when we are talking about the plate tectonics in brief way, and then we will learn more about that but these are the locations which are the locations where we expect the large magnitude earthquakes in the region

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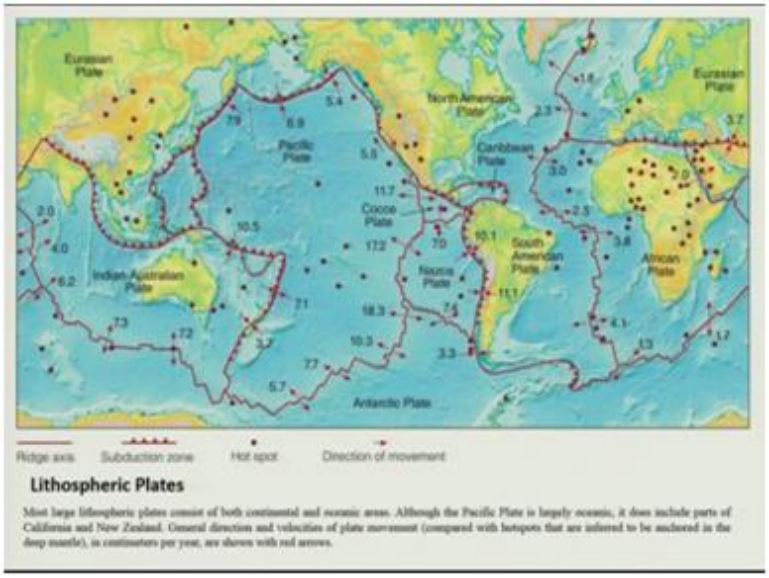

So we have the distribution of the the Oceanic and continental plates and we also understand that the plates are either subducting with respect to one another or they are sliding possibly by with respect to another for example here the Pacific plate is moving in this direction as well as it is subjecting and the North American plate is moving in this direction, okay. So and and here also the arrows which are been shown are indicating the direction of the movement of the plates.

And then either we are having the subduction zones or not this details we will talk about when we are talking about Noranda plate tectonics but but the important point here which I would like to mention is that these are the locations really will expect the large magnitude and make a earthquakes as well as in this region which is the part of the India and we will expect the large magnitude and make earthquakes.

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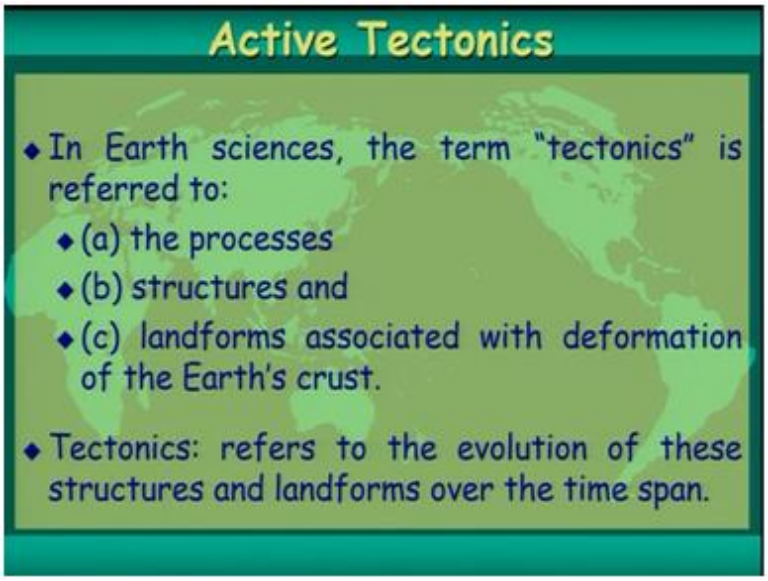

So how often do earthquake occur around the globe, so this will be the basic question which should come in our mind that how often we have, we will keep talking about small magnitude earthquakes, large magnitude earthquakes or great earthquakes. But how often those earthquakes are occurring and I would like to emphasize here is that the when we talk about the magnitude in terms of the magnitude magnitude is associated with the amount of energy which has been released.

And this energy is we would talk about the strain which has been accumulated over the time because of the ongoing deformation, so if you talk about one magnitude and if you go to second or two magnitude then the differences in terms of the energy is almost 30 times more. So if we say that okay eight magnitude earthquakes in Himalayas are likely to occur and then how many small magnitude earthquakes are more than magnitude earthquakes will suffice that amount of energy which will be much larger

So much large number of earthquakes will be required of moderate magnitude or small magnitude to suffice one single eight magnitude earthquake. So on earth as we know is a very dynamic planet and one of the it is active region so Earth comprises several active tectonic boundaries which are between the tectonic plates or lithospheric plates hence earthquakes always occur are occurring somewhere on the earth because of the ongoing deformation there.

Because this or these plates are moving there within particular speed with respect to one another so the National earthquake Information Center any IC locates about 12,000 to 14,000 earthquake of different magnitude each year on an average, earthquake with magnitude less than or equal to two occur several hundred times a day worldwide. So this shows that the the earth is quite active we may not be able to notice or experience or the two magnitude earthquake.

But of the seismometer will record this, and this shows that there is some movement which is going on beneath the earth and along the plate boundaries, further if you look at the major earthquakes with magnitude greater than seven occurs more than once per month, so it is this this planet is not quite it keeps on triggering earthquakes. And if you talk about the great earthquakes which are having the magnitude greater than or equal to eight.

They occur once a year around the globe. So we do not know that when such large, great earthquake will occur in Himalayas but I would say that with the help of the palid seismological studies and the GPS measurements to some extent we understand that which are the locations which have accumulated they strain over the time or energy over the time and are likely to trigger such great earthquakes and in particularly in Mali

now coming to some terminologies which are going to be important for us as active tectonics so these are what we are talking about the tectonic moments, so active tectonics in earth sciences the term tectonic is referred to a the processes structures and see the landforms associated with the deformation of the earth crust. So what are the processes which are involved? So this part we can talk when we are talking about the interior of earth to some extent as well as the seismic waves and plate tectonics.

And what type of structures we see as in case of the manifestation on the Earth's surface and those are the landforms which are associated with the ongoing deformation? Then tectonics refer to the evolution of the structures and landforms over the time span. so for example; as I told about that Himalayas as a result of the ongoing tectonic deformation so we have higher Himalayas we have less in Himalayas we have some Himalayas or we say show Alex.

So in terms of the elevation also if you see the high Himalayas are having the elevation more than 6000 metres and then coming down we have around 5000 or 4000 and then to 2,000 or thousand meters. So these are the different ranges which were developed over the the large span of time and these are the results of the ongoing deformation so this the tectonic deformation is referred to the evolution of the structures okay and associated landforms.

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Further on a global scale we are concerned with the origin of continents and ocean basins which are the largest land forms produced by tectonics on earth so what we were looking at the distribution of the lithospheric plate either it is in continental plate or machining plate they have resulted into the formation of different landforms either they are the elevated portions or they are having depressions, so we talked about the basins okay.

Now these are all on the global scale, but coming to the regional scale we are interested in structures that produce mountain chains on the largest scale we are talking about the ocean basins and mountains or the continents either it is oceanic or the continental plates but on regional scale even then, we come down to talking about that how this deformation is responsible for developing or producing the mountain chain.

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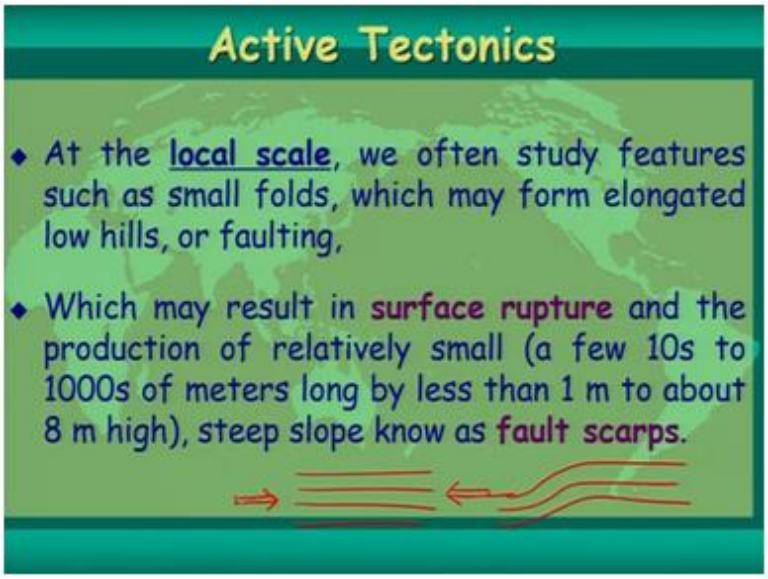

Then comes down to the local scale we often study features such as small folds these are all structural features and geological structures folds which may form elongated low hills or faulting. So what I would like to emphasize here is that we are coming from the global scale we are talking about coming to the narrowing down to the local scale okay so coming to the particular site.

So we talk in the broader sense that how this all plates or the continents are distributed, and then what are the Associated deformation? and what are those any large scale features narrowing

down to a particular region? So this is what we see is on the local scale and local scale which may result in surface ruptures and the production of relative small, a few 10's to 100's or 1000's of meters long by less than 1 meter to about eight meter high scarps.

And, this scarps or the deformations are termed as fault scarps. So a one sketch which I well I drew in the previous lecture about the fault scarps, so particularly those are the the features which we will talk when we are talking about the local scale so in history we start in the palid seismological studies basically we look at that what is the global techtronic framework then we come down to the local and the region of one.

So this part will remain almost common for all such type of studies so we see where what type of deformation is taking place on the on the global scale and the regional scale and then the local scale and what are the Associated features, so we say in the on the larger global scale we talked about the plate tectonics the subduction zones or the collision zones then we are coming down to the regional scales we talked about the development of the mountain chains and all that.

And further local scale we talked about the smaller features like fall fault joints okay and mostly the surface ruptures that is the the fracturing or the displacement which we will observe on the surface will be manifested in form of the fault scarps. So if we talk about me like I will again draw on sketch here so we have the layers here, and then if you deform in terms of the compression tectonics regime and what you will see is the deformation like this okay.

So these are the fault scarps okay what you will be able to observe on the surface so this I have drawn this section so

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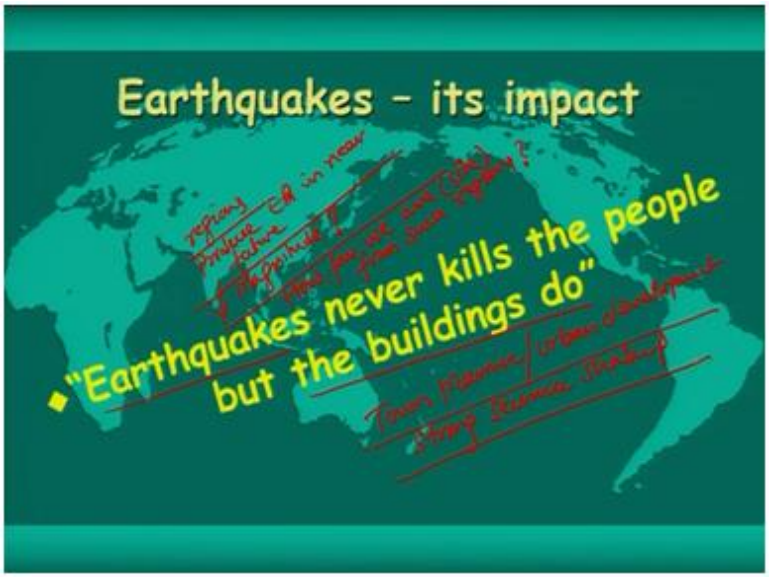

Further earthquakes and its impact, if you take so this is an tagline which talks about that "earthquakes never kills the people but the buildings do". So mostly, most of the people will be killed during an earthquake because of the damage so it is very important and significant for us to locate such locations or the regions okay which are likely to produce earthquakes in near future okay, and what will be the magnitude this will be the question, how far we are that is the site from such regions?

So for example if you are if you say that okay fine this is what you have the the Himalayan range and how far you are sitting from Himalayas? Then this will be extremely important if you are sitting here and of course and then you are having the subduction zone so depending on that how far you are sitting and whether you are close to the deformational area or the deformation zone that is also going to bother you, but even if you are sitting away from such regions.

One should definitely take into consideration that what will be the the magnitude of earthquake so earthquakes never kills the people but the building's too so this information will help basically the town planners or Urban Development to take into consideration but what effect they will have okay on a particular site because of strong seismic shake. So these are a few important points which we should keep in mind when we are moving ahead in this course, So for example

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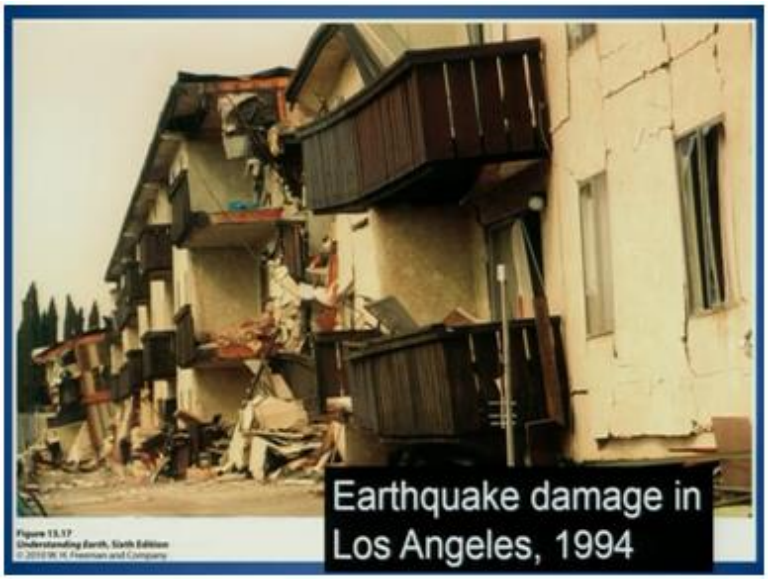

As I told that earthquakes never kills the people but the buildings do these are few examples which I am highlighting here is this is the earthquake damage which occurred in Los Angeles in 1994

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Then coming to 1985 Mexican earthquake the pattern of damage you can see so basically what we are looking is the poor construction without having an proper understanding that what will be the amount of or the intensity of ground shaking by a particular earthquake in that region.

So this lack of knowledge whether it existed before the answer is to some extent yes because the earthquakes occur or the recurrence of the earthquakes which earthquakes are more than 400 or

500 years. So people tend to forget very fast but which fault or which area is due in producing the earthquake in that cycle, so you may have a number of earthquakes in a gap of 50 years or 40 years or 100 years.

So once you say that, you told that it is the recurrence is 500 years, so no earthquake is going to occur in 500 years, but no which area, the different areas will have the different recurrence interval so different fault lines may have the probability of triggering the earthquakes at different point of time. Now the best example which I can highlight here is that in 20th century we had experienced three major large magnitude earthquakes in himachal.

And those rare 1905 kangra earthquake with magnitude 7.8 then we had 1934 Bihar Nepal earthquake with magnitude 8.3 to 8.5 and then round 8.4 was 1950 Assam earthquake so in just a time span of 50 years we had the three mega earthquakes or we can say not Ming up at large magnitude earthquake occurs so we need to be prepared for this okay.

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1995 earthquake damage in Kobe now these are the regions which I am talking which are very prone or extremely prone to earthquakes so, whether Japan was not ready for such a damage the answer is yes but after 1995 they have done extensive studies to identify such fault lines or the regions or the areas where the likelihood of future earthquake is certain I will give a small lake chair particularly the damage pattern.

Not only the damage pattern but we will talk about the rupture pattern surface rupture or surface manifestation which was by 1995 Kobe earthquake in one of the lecture but here if you see this is the damage pattern one of the Express Highway and the flyover which was toppled down because of the strong ground shaking but up shell was far far away this was in Kobe and this is far away from Kobe where the surface rupture to place.

So this is what they have done as a wonderful way to reach the local people or the citizens of that country and make them understand that what exactly happens during an earthquake, so this is one section which you see the the line here this is an fault plane along which this block of the rock block or this of the surface has been raisin or moved up okay. So I am NOT going into the detail of this but we will talk about thus these are these are typically faults okay.

And this manifestation which you see is the fault scrap, so they have preserved this and created a museum to reach people or the local citizens. So this is what they are having the outreach programs but in India we have not done this because the last earthquake the major one which we experienced with such deformation was over in 20th century but we may have been able to identify the rupture of 1905 Kangra earthquake in Kangra valley.

I will give a lecture on that also so you will understand that what we are talking about the fault scrap what we are talking about the faults and all that but in short as we have been talking about the tagline that the earthquake never kills people but building do so this is the pattern of damage which was experienced in 1995 Kobe earthquake and this example shows that how the deformation is manifest rated on the surface.

So movement along this one this in section and the surface manifestation there is a scope so this block has moved up here as compared to this one.

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Then this was 1999 chichi earthquake in Taiwan which shows the fault scrap here, so the this was the deformation was manifest rated or the manifestation was seen and passing through one of the the pavilion and the running track which got displace, and default again then the damage here again of the garage.

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This was in 2001 Bhuj earthquake extreme damage was been experienced in Bhuj.

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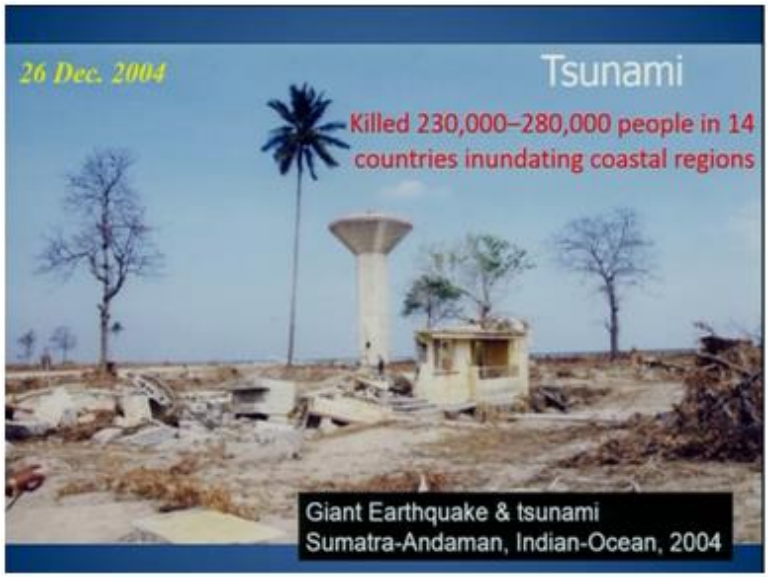

Then a giant earthquake and associated tsunami in 2004 this photograph is from carnico bar where total damage was experienced the people and many Indians who got killed in this one. So almost like around the Indian Ocean if you take almost like 230000 to 280000 people in 14 countries we have been affected and killed actually this, but not it is just affected but they got killed so pretty large number of population was killed because of the giant earthquake in 2004.

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There is another photograph from the same area car Nicobar.

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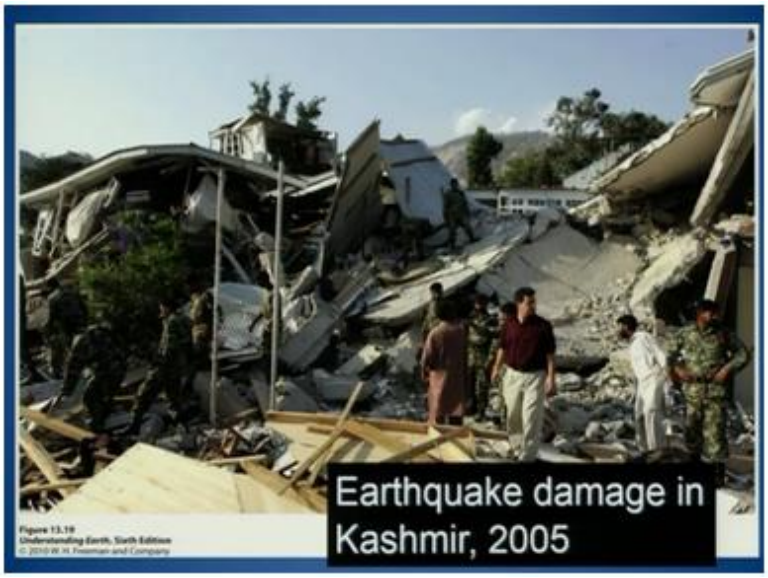

Then 2005 was the Kashmir earthquake almost 80,000 people who have been killed.

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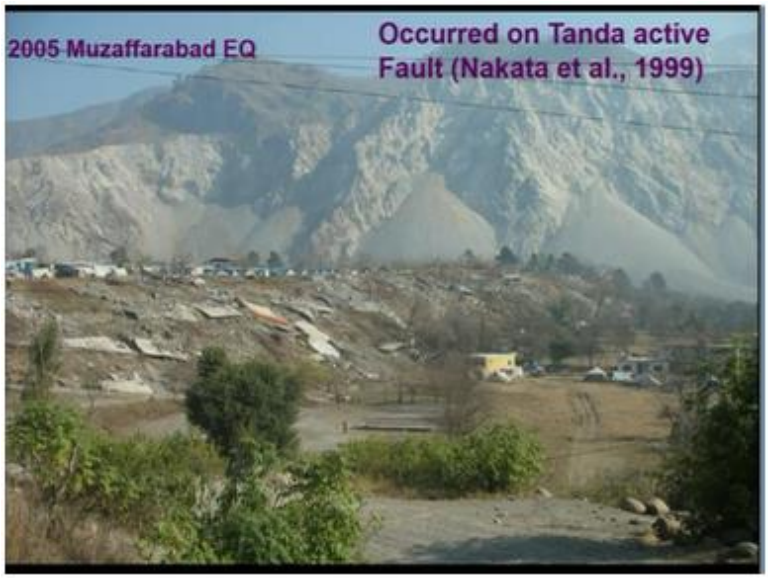

Now I just would like to emphasize here, it is not the fault which was responsible for triggering this 2005 earthquake muzaffarabad earthquake or Kashmir earthquake the this fault was been identified way back in 1999 by Professor Nakata of Hiroshima University and this person he extensively worked in Himalayas and he was the first to give us the nomenclature or I would say that the the name for the the frontal fault that is Himalayan frontal fault.

And he gave that how active faults or the technique, how the active Falls should be identified now he reported this about the the thunder active fault in Kashmir or in in Pakistan that this is

one of the active fault which will trigger an earthquake in near future. A report was been submitted to the Geological Survey of Pakistan but they mocked on him they did not bother about his finding and finally they experienced the same in 2005.

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Then there was 2011 giant earthquake of Tohoku magnitude 9.1 and the previous one which we were talking about Kashmir was 7.8 or 6 and then 2004 the Andaman, Sumatra was 9.3. So total damage was experienced in some part of Japan almost 19,000 people got killed. And this one this also will we will give a lecture talking about that what are the findings from Japan or the colleagues and Japan which they have done the research in this area.

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This is again another photograph usually in Japan what they do is to protect the areas the coastal areas they try to construct a wall, and this is the tsunami wall which was been constructed taking into consideration the previous records. But let me tell you that they were very much aware and that they may have a larger tsunami then what they have experienced or they have they have noted here.

Because there was one Geoghan tsunami around 8, I am not remembering the exact year but it was 8 95 80 or so but we will talk in detail when I am talking about the tsunamis how the the events from Japan. So they they had this understanding because neither search which they did clearly indicated that the the next tsunami which they are expecting in this region may be much larger than what they expected. So if you see this is this photograph is before the tsunami and.

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This is after one okay so the water which completely toppled down in the wall so this wall which you see here now the next slide you what it shows is the the water is coming the tsunami waves have all almost topple down so you can just have the and the mark marker here one is this board here and others this house here okay and you cannot see the wall because the water is coming know about that okay.

So this was the condition now the situation in which Japanese people experienced in 2001 Tohuku earthquake.

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Coming to the gorkha and kodari earthquakes in Nepal 2 earthquakes took place in this region in 2015. The damage was not so severe, but of course it was bothering for us actually. So this was the building one of the school building which collapse the columns were broken because of strong ground shaking near Kathmandu.

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And this was the the tower which collapsed and many people got killed and this one, so almost 10,000 people were killed during this earthquake in Nepal.

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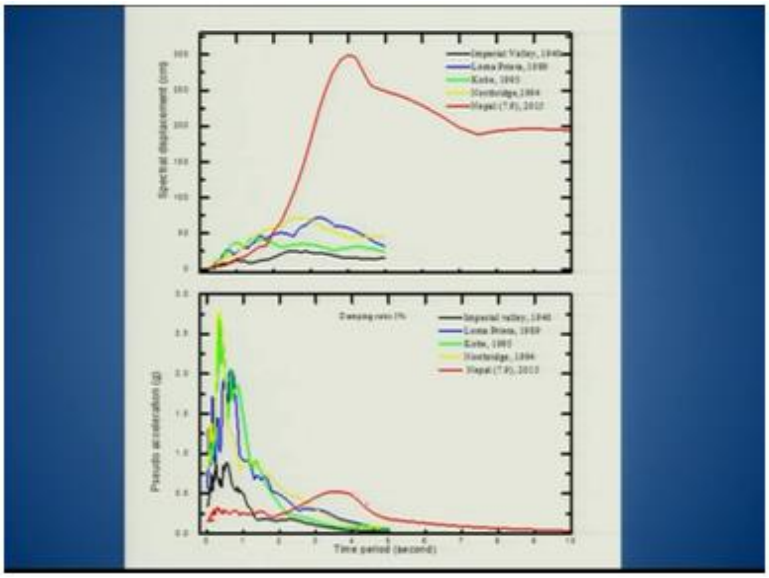

Now the the reason which has been given for the comparatively less or moderate damage is it is been shown here, that the the ground acceleration which one could have expected in among the earthquake of magnitude 7.8 or 7.9 where the similar magnitude earthquakes have been listed here Imperial Valley earthquake, 1940 Loma Petra 1989, Kobe 1995, Northridge earthquake u.s. and 1994 and then the Nepal one.

So in terms of the magnitude these earthquakes are very much similar so what we we expect us that similar amount of energy was released but sometime the complex nature of the crust will teach us a different lesson, so the this earthquakes which have been shown here by this yellow green blue and black lines are very much sitting, so they immediately after the the earthquake you know triggered the ground acceleration was picked up here.

So very strong round excitation but what happened in terms of the Nepal it was not very slow and you can see the the graph here is very broad here and then the the ground acceleration which was which could have been expected as based on these earthquakes was not at all similar so it was very gentle swing which we experienced okay, so the damage was not not much because of because the ground acceleration which was expected was not up to the or similar to what was been experienced in previous similar magnitude earthquakes.

So this was one of the reason for that but this will never remains the same the same magnitude earthquake may have different type of damage and ground shaking. So we are blessed that this event was not similar in terms of the ground acceleration of Northridge co-pay Loma Petra and Imperial.

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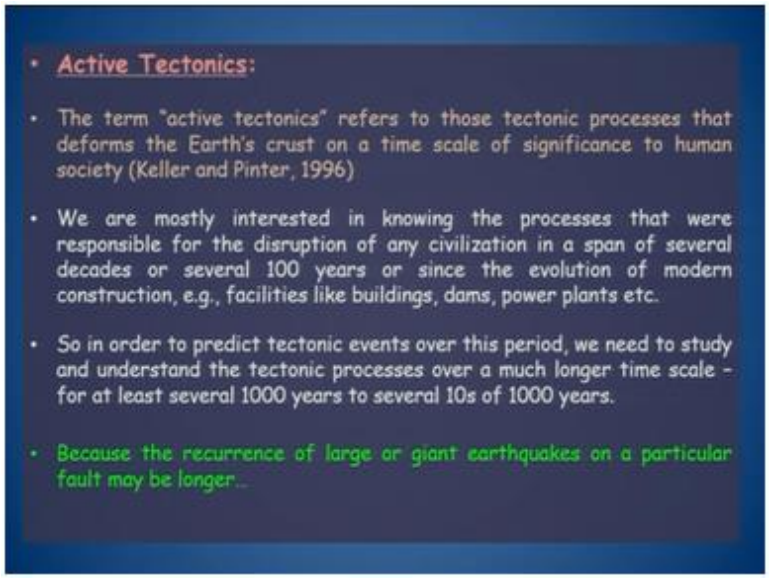

So active tectonics further if we look at the term active tectonics, refer to those tectonic processes that deforms the earth crust on a time scale of significance to human society. What does this indicate to us? That we are interested at this stage talking about the the palace's phonology and all that we are interested in understanding the tectonic processes on a time scale which is significant to the human society.

We are mostly interested in knowing the processes that were responsible for the disruption of any civilization in a span of several decades or several hundred years or since the evolution of modern construction. example facilities like buildings dams power plants etc because these are the life line structures which will be damaged or destructed or we can say that earthquakes can affect the whole settlements.

And in past there are signatures or the evidence which tells us about the human transfer because of major earthquakes and let me give you the example which we have been able to pick up from kutch region as the hairpin settlement. Based on our studies we have inferred that there were two

to three major earthquakes during that period that is almost like 4000 years back in two thousand years back there were major earthquakes which will responsible for the decline of Harappan civilization.

And the evidence which we caught where are related to Dholavira and subsequently from the great run of kutch close to the indo-pak border so we will try to focus when we are focusing on cuts region. We will try to give one lecture on that but also so basically we are interested in understanding the active Techtron ism which refers to the tectonic processes significance to the human society and mostly we are interested in knowing such processes how they have affected.

And whether they will be responsible for disrupting the any major civilization or they've the very responsible or they will be responsible for damaging the buildings and lifeline structures like schools, hospitals, dams. power plants etcetera. Now further so in order to predict tectonic events over this period we need to study and understand the tectonic processes over a much longer time scale.

Because and that time scale could go up to ten thousand years as I told in the beginning because that will tell us not what is the pattern of ongoing deformation and will help us in understanding overall process because the recurrence of large or giant earthquakes on a particular fault may be longer so if we we study a very small span of time say 100 years we may end up saying that although there is no earthquake future but there may be an evidence.

Or signature which is sitting in the sediments or the landform which talks about or tells us about the earthquake which has occurred I have 10,000 years or thousand years back or close to 10,000 years back. So as I told that the 2001 kutch earthquake was not expected and the expectation was not there because we never knew about that what is the past history of that region but now since we are we have started studying or doing the research in that particular area.

We can say at this stage not the kutch region has capability to trigger much much larger earthquake as compared to what we experienced in 2001. And one of the example of course the magnitude has been under sized for 1890 in 11th earthquake in create an offcut but the features

which we we observed signatures and the landforms as well as within the sediment succession it clearly suggests that a certain they there are chances of having much larger earthquake as compared to what we had in 2001.

And those earthquakes the Palio earthquakes the ancient earthquakes were responsible for decline of the happens Elijah. So we need to study the much longer record of the earthquakes or the the processes to understand the the overall tectonic deformation.

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So further about the active tectonics an active tectonic process which is likely to produce a catastrophic in both the major or great earthquakes. However moderate sized earthquakes also can produce catastrophic the case which we have experienced I am in the Paulo earthquake recently in 2018 but we should not underestimate the moderate earthquakes, particularly if they occur in densely populated areas where buildings are constructed of material that cannot withstand seismic shaking.

So even moderate earthquakes with magnitude 5 or 6 will be dangerous if we have the poor construction so this is one of the point which one should keep in mind. Houses constructed of and reinforced cement blocks and bricks or stones are particularly hazardous or buildings constructed on thick layers of unconsidered sediments particularly those sediments within high water table or high water content.

This or such areas will be extremely vulnerable even if you are having moderate magnitude earthquakes so as I was talking about we have primary features and we have secondary features. Similarly to that we have the deformation which is taking place close to the defaulting region or seismically active region away from the such regions.

So this is one of the point at the end which we have talked about that if the construction is on thick alluvium will be responsible Warrnambool for from the earthquakes which are occurring how far away from those areas okay I will stop here thank you very much and we will continue in the next lecture.