Earthquake Geology: A tool for Seismic Hazard Assessment
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Lecture No 3
Introduction to Earthquake Geology (Part-III)

Welcome back so in last lecture we discussed about few important points about the active tectonics and we also talked about the Paleoseismology and what is the importance of seismicity particularly the significance of seismicity in terms of the Indian subcontinent. As I told that we will discuss in detail when we are covering this those topics now moving ahead this was the last slide which where we stopped on the active tectonics.

And mostly we were focusing on that are the earthquake not killed like usually earthquakes are not responsible for killing the people but buildings the damage which has been experienced during the ground shaking due to earthquake kills people.

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So the construction part is extremely important but the better construction can be done which can withstand the seismic shaking can be done only when we have the complete understanding of the Paleo seismology or at least we can say the earthquake process. But in this course as I told that we will be covering on earthquake geology part. So maybe we will be looking at that what are the signatures of such an earth quakes on the Earths surface as well as in the sediments.

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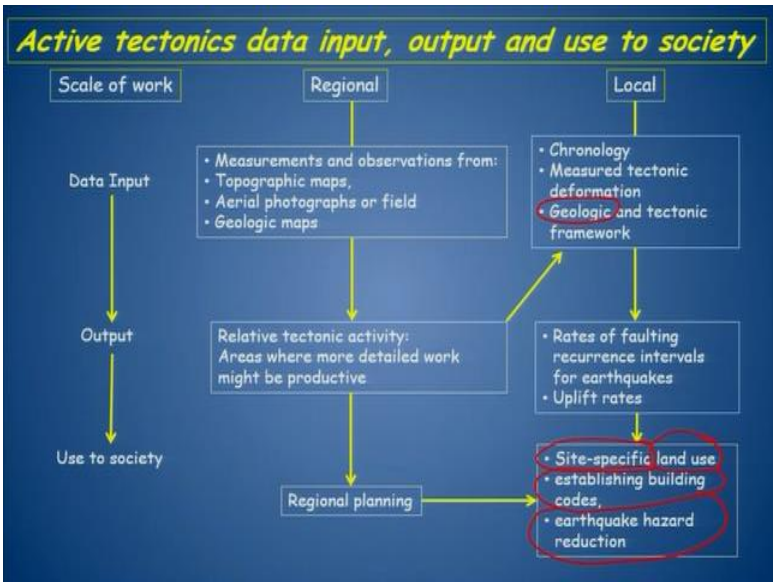

Now further moving to this part active tectonics data input- output and used to the society. So the how this active tectonic part is important for or it plays an important role for the society. So there are a few things which if we can discuss in this and the step wise that what data we should collect and what are the inputs the scientific inputs basically we told and then what will be the output and how best we can do.

So overall exercise which we are talking here as the title of this course itself says that it is towards the implications through the seismic hazard assessment. So it helps in the producing the or minimizing the seismic hazard. So scale of work as we have we talked about that that is from the global scale we come to the regional scale to the local scale similarly to that, so we are coming to the regional and then local scale.

We are coming down to the narrowing our studies and focusing our studies to a particular site of our interest. Okay? So and now this depends upon that site of interest depends upon the urbanization. Okay? So if you are going for urbanization or you are going for some industrial setup then those sites are to be surveyed first before getting into the business of construction okay?

So data input is very important and then finally yes of course the output and based on the output you can judge not whether the area is safe or not and if not safe then what best precautions or these remedies or the strategies you should plan to make the area relatively safer. Okay? Then so the data input whatever the data is available with us in terms of the

active tectonics or the seismicity and with the input of the scientific inputs we have the outputs which are useful for the society.

So regional scale if you take then what we do is the measurements and observation from topographic maps then comes the aerial photos or field surveys and the geological maps. so these are the inputs which can put four of in terms of the active tectonics and the observations which you can make using the topographic maps, aerial photographs or satellite photographs or geological maps.

So basically we are talking here about the field techniques and all that, so we will be coming to this part and coming few lectures and then what are the existing geological maps that you can use and topography, topographic maps usually will be helpful in talking about mapping. What type of landscape you are looking at actually, then based on that the output will be but what that is a relative tectonic activity you can understand areas where more detailed work might be productive.

So you can identify certain areas and that can be done based on the inputs which you have collected over here at the top that is the measurements and observation of the topographic maps from the topographic map from satellite data or aerial photographs and from the geological maps. so whatever the publish information is available we can input that and the output can tell you that whether this area should be studied in further detail or not in terms of the relative tectonic activity, then this input goes for the society.

And that what I was talking about mainly for the regional planning, so you either you are coming up with some industrial area or residential area or a city here planning because now in India a lot of places we heard about or and we keep on seeing on the news that we are going to have and smart cities, Okay? And either the old cities are been going to be converted to the smart cities or the new sites will be identified where you are going to have the smart cities, so whether those smart cities are safe or not?

But other than that I would as a citizen of India we I would say that why not to look or look at the cities, existing cities and towns and villages. Okay? Because they are also not as safe as we have been talking about then coming to the region, we come down to the local scale.

Where we do more detail studies as we can we have pointed out here in the in the second one, so the based on the basic information which is available with us.

We can take a decision whether we need more detailed studies in a particular area then we do chronology, measured tectonic deformation and through measuring the tectonic deformation geological and tectonic framework and all that. So this is basically the part of the methodology to some extent but yes of course we are going to cover in more detail about the field techniques.

As well as the methods which we are going to use to identify the earthquake features are not warm and earthquake and associated earthquake related features and associated landforms. so basically here we are talking about the ages of the landforms and then based on the ages or the dates or we can prepare the chronology of the tectonic events and you can also measure the tectonic deformation this can be done using the GPS.

And also to some extent you can back calculate the tectonic deformation know process using the chronology. Okay? So that you can talk about the slip rate you can talk about the uplift rate and so on and also one can discuss about the geological and tectonic framework and this is on the on regional as well as on the local scale that what is the implications of the geology and the tectonic framework or the structural framework of the region on particularly on the active tectonic part

Then as I told that based on this chronology and major tectonic deformation one can talk about the rate of fault, the recurrence interval and the uplift rates. So one can discuss about this so this you can do at the local scale and further finally the site-specific land use. okay? So the ultimate interest of our interest is they look at the site-specific conditions and basically the land use part. Okay?

So if you have the information about the defaulting rate and all that then you can also talk about the magnitude, you can also discuss about that what will be the probability of how experiencing an earthquake in near future and that with the help of the magnitude and the geology. So based on that he will be able to talk about that what will be the effect on this particular site and based on that the structural engineers can go for the establishment its establishing the building codes. Okay?

And the ultimate goal is the hazard reduction, so this is the ultimate goal of the whole exercise, okay? So we want to reduce the hazard. we are not saying here or we are not claiming here that we will completely like make you safe from this as hazard know it is not possible to me we cannot stop earthquake. Earthquake is going to occur and the processes which will trigger the earthquake are already on and they will never stop. Okay?

The main stop but there is no answer right now with us. Okay? so the processes are on and so earthquakes will are going will occur definitely in future and the so the best remedies which we are trying to do is not how to make our houses safe, out make our people safe from this hazard that is the ultimate goal of this whole study.

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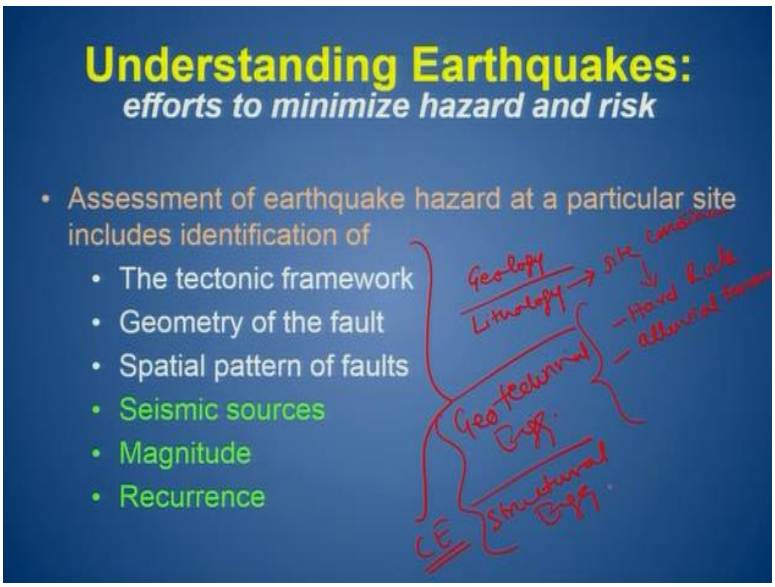

So basically to minimize the hazard and risk, okay? We need to understand the earthquake process. Now in this we understanding earthquakes basically two efforts are towards reducing the hazard and risk. Okay? So what one can do is that for this assessment of earthquake hazard at a particular side should be done very precisely which includes identification of one Your the tectonic framework.

So you are talking about the regional scale you are talking about on the regional scale what is the tectonic the structural or tectonic framework and then you are coming down to the geometry of the fault so you are narrowing down your studies you are coming down to the local scale where we talk about the fault geometry and this what is the fault geometry and what types of different faults are there.

I will talk in coming lectures because these are extremely important aspect which will play an important role know geometry of the fault in will we are talking about the hazard and then comes the spatial pattern of fault how it behaves along the strike and it is extent. Then we talk about the seismic source, how deep the earthquake is okay and the magnitude of the particular earthquake and the recurrence finally.

So these are few bullets which are I would say of course they are important and for the assessment of earthquake hazard at a particular site. Nevertheless along with this you would say that why you are not talking about the geology part Okay? Or we can say the Lithology you know geological language okay we can say the Lithology that is we will talk about the site condition.

So whether it is like the site is sitting on hard rock or in on alluvium or alluvial terrain, this will play an important role and this portion usually has been taken up by the geotechnical engineers. So along with this we are talking about the tectonic framework geometry of the fault, spatial pattern of faults, seismic source. So some of the portion the geologist to some portion has been done by seismologist

And then the rest of the portion which we talked about because we get into the building codes and all that and what type of construction should be done so geotechnical engineer along with the structural engineer. So this goes as a part of civil engineering where people talk about being us safe buildings and all that the building codes and what type of foundation one should have and what type of building one should have and depending on the geology of the region that is the site condition.

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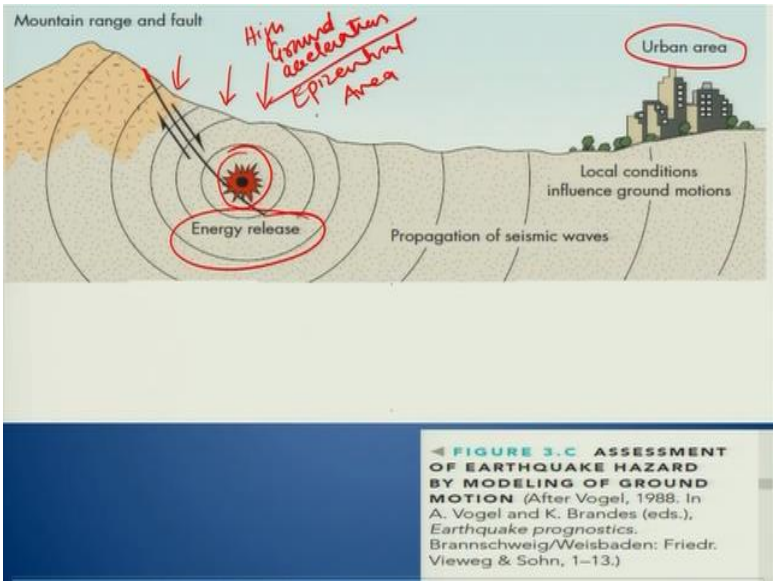

FIGURE 3.C ASSESSMENT OF EARTHQUAKE HAZARD BY MODELING OF GROUND MOTION (After Vogel, 1988. In A. Vogel and K. Brandes (eds.), *Earthquake prognostics*. Brannschweig/Weisbaden: Friedr. Vieweg & Sohn, 1–13.)

So the whole idea behind this exercise is one is that what is the seismic source at what depth you will have an earthquake and what is the surface manifestation of the fault whether the fault is a normal fault so basically what we classify is I will come to that later but we say normal fault, reverse fault and the thrust faults or strike-slip fault. So here what we see is a normal fault this block is going down anyway but this is the expression of the fault on the surface.

And this will be what we are talking about the depth of an earthquake and the propagation of the seismic wave so energy has been released the maximum energy has been released here so this portion okay? Which is sitting exactly on the non above the focus of an earthquake where the energy has been released will have high ground acceleration. So this is in what we call epicentral area but this location that is at any urban city or site of interest is sitting far away from this one. Okay?

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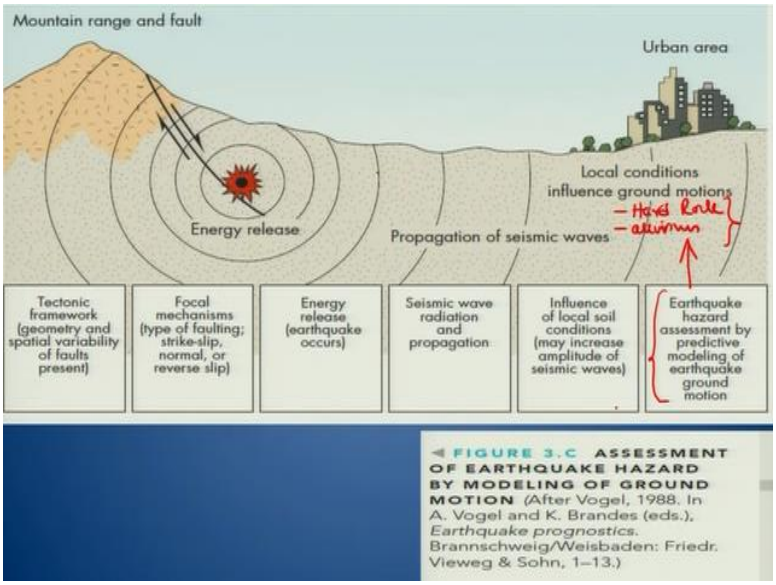

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So the part which we will be interested in that how far this city or any urban settlement is located, so the distance will be a big question, okay? How many kilometres? Because for example like we had and this earthquake of 2015 Nepal magnitude 7.8 or something like that, Okay? and it shook the areas almost more than 300 kilometres. Now again and depends on that because the propagation of the seismic wheel will not differentiate between any boundaries of countries or anything no international boundaries.

We will talk about it we will just move through the interior of Earth as well as on the surface of the earth. Okay? So local side condition is important and this you will be able to understand when we are talking about the seismic waves. So local site conditions are important, so whatever we have been talking we talked about in the in the previous slide the most important part is the source, the location of the fault.

What is the amount of energy it will be released because this is going to talk about the magnitude. Of course another point important is the depth and what depth this earthquake has occurred and the local conditions, and how far we are sitting from this source so for this full understanding what we need is one is the tectonic frame but we should understand, should know the geometry and deception very variability of the fault present and that particular area.

Focal mechanism that what I was talking about that whether the faulting is a strikes the fault normal fault or reverse slip fault this we will clear when we are talking about the different type of faults but please remember this and you can back refer this to understand what we

discussed in the faulting pattern because each type of faulting is having a different environment energy is released that is earthquake occurs.

So at what depth the earthquake has occurred that is important seismic wave radiation and propagation. So depending on that at which location your earthquake has occurred and from where the seismic waves are likely to be propagated towards your site of interest again and then the influence of local soil conditions and this is important may increase amplify magnitude of seismic waves.

So as I was talking about that the local site conditions either we are sitting on hot rock or alluvium then this two sites are going to behave differently so this is important and then earthquake hazard assessment by predictive modelling of earthquake ground motion. So you can predict of course but not so precisely but this prediction is mainly for the ground motion. So one can predict that more at a particular earthquake magnitude this will be the groundwork motion which is expected in a particular area.

And that will depend upon what we are talking about the site conditions and this you can predict and you can model okay so based on this one can use this information for building core development and all that.

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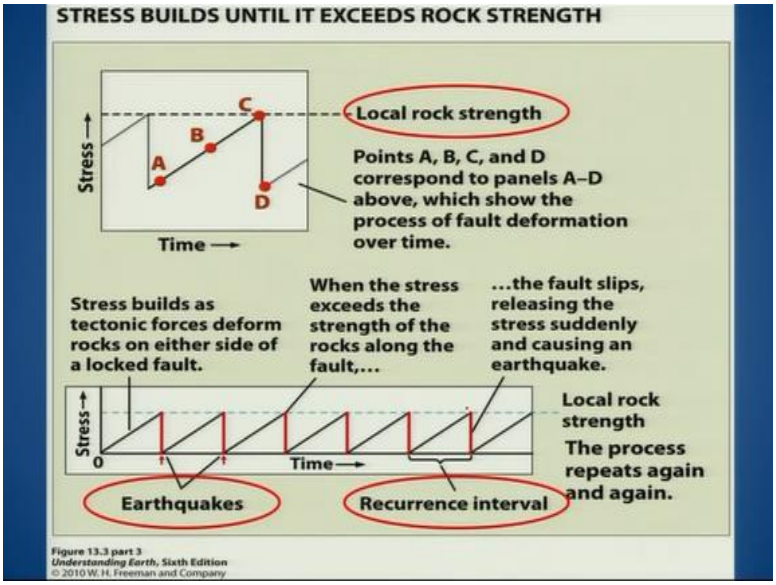

Now coming to the further the process part little bit so usually what has been seen as not the earthquake is going to recur again and again so if you have not weak zone, so energy which has been stored. Okay? That is the strain which has been stored within the rock bodies will be

released along the week zones and this is a very fundamental understanding. So what are those weak zones? Those weak zones are fractures or faults along which the displacement will take place and the earthquake will occur.

And the moment or the slip along the default will occur during the process of earthquake and then it will be ceased and then it will remain locked until it acquire or accumulate the strain again, until again, until it releases in during the next event. so there is a cycle what we see okay? But the stress again will affect the strength of the rock, so this is what we are trying to tell here okay?

So one is the local strength of the rock if it remains the same, so over the time what has it been shown here the point A, B and C and D corresponds to panel AD okay? So this is your AD above which shows the process of faulting and deformation over the time. So you have the time here so this is your time and this is the stress reaches you are applying okay? So over the time it will build up these stresses the building up and this will be the point where it will release the energy. Okay?

So and then after that again it grows, okay? And the time comes it will release. So this particularly what we talk about is the recurrence interval. Okay? So these are the earthquakes which I have been shown here and over the time. So you have stress builds as tectonic forces deform so as I was talking about in one slide in the last lecture that we have the plate motion is there and plates are colliding.

So those stresses are building up along the body in collision zone or subduction zones or the transformed all zones. So the tectonic force deforms rocks on either side of the locked fault. So for example; if you see here suppose you are having the two blocks of the rocks and there is a weak zone this is what I am showing here, so to some extent it will be locked. If I am applying pressure here from both my hands, okay? And then there is a pressure is developing between this but it will be locked.

But the time will come in the rocks, okay? it will slip. Now this sudden slip is your event and this is what has been shown here, so you have the earthquakes here and further the time lag between this two, Okay? Or an event is your recurrence interval. Now the question is not whether this cycle remains the same over the time and if answer is yes then we will always

expect a similar magnitude earthquake at a particular recurrence interval this is one thing okay?

So we will be able to predict very precisely that, after so many years I would say that precise means not exactly like Baba's like we can say that this is then as Curie the compiler, we cannot say that okay? But of course we will be able to precisely tell that okay after the hand 200 years or 300 years 400 years the next earthquake will come again provided what we understand here it remains as it is. Okay?

That the strain is developing here and released strain is developing here all the time introduced so this interval remains the same. So we can say that this is earthquakes which are occurring in the given time. We will have similar magnitude because the stress which is applied and the strain which is getting accumulated is almost same to trigger the same or similar magnitude earthquake.

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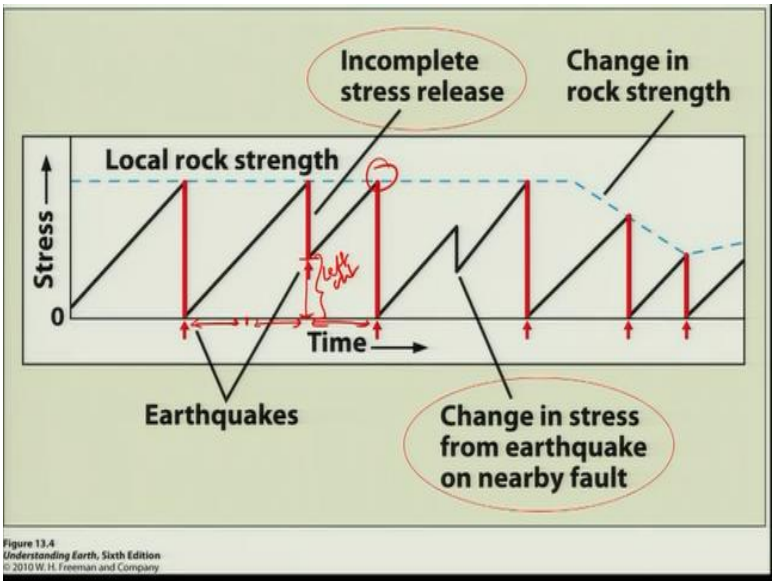

But that never happens in nature, because the earth is a dynamic planet at complex planet. Okay? And complexity is in terms of also is in terms of the material of the crust, crust is not homogeneous. so and the any material you break will lose out the strength over the time so every time you keep on fracturing the same place the strength will vary. So this is what has been shown here. Okay?

So you have local strength of the rock then, sometime you have an larger earthquake the whole stress or the energy which was accumulated was released here and then started

accumulating, accumulating, accumulating and the time when it came okay was similar to this it did not release the full complete energy or the stress which was accumulated. So this we call incomplete stress release.

What does that mean that over the time, over the time, the same time again this one as well as this one, okay? The same amount of time has been taken but the earthquake which was the energy which was released here was not the same here. This means not you may expect another earthquake in a very short time and that is what has been shown here but because of this incomplete release of the energy here still this much was left out with it and the just half of this was released half of us left out.

So again just having a time span half of this, okay? So you are having what has been shown here with half of this one again was just taken up to trigger this event okay? And over the time again because the change in the stress from earthquake or near fault is changing the strength of the rock is going to be affected. So we will stop here and will continue in the next lecture. Thank you so much.