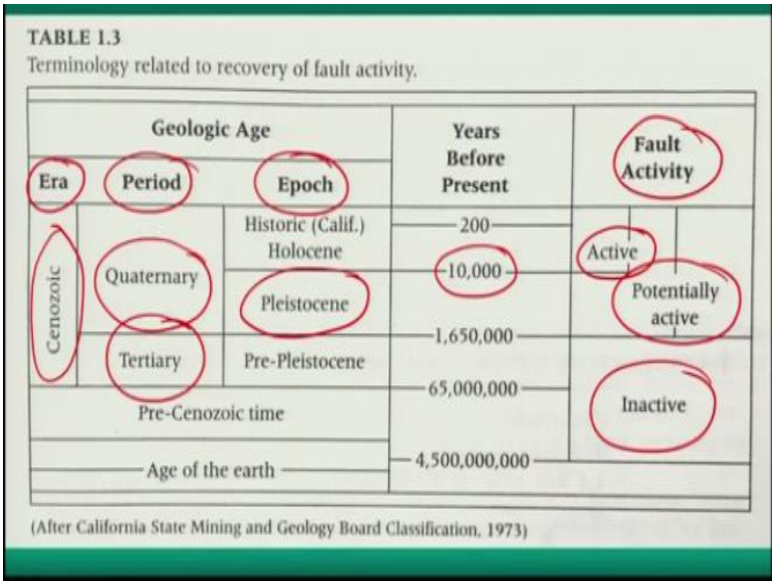
Earthquake Geology: A Tool for Seismic Hazard Assessment
Prof. Javed N Malik
Department of Earth Sciences
Indian Institute of Technology - Kanpur

Lecture – 05
Fundamentals Related to Paleoseismology (Part I)

So, welcome back, so in previous lecture we discuss mostly about the terminologies and as I told that to some extent it is important for us to understand the, or know about the geological time scale, we discuss about the era period epoch.

(Refer Slide Time: 00:34)

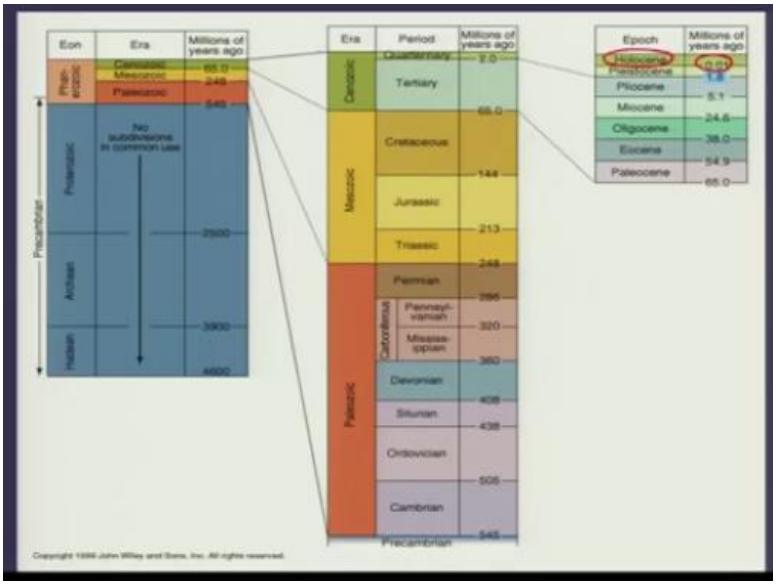


And the most important epoch for particularly, our studies of values is paleosiesmology, an active fault is your quaternary period, so in quaternary period which we have the epoch Pleistocene and Holocene and as I told that if you take in terms of the years, how many years back we should go in terms of the geological time, then 10,000 years is quite good enough to understand the seismicity pattern and all that in particular region.

Of course, you can go further below that, that is your into the tertiary part also but as we were talking about that if you are within the quaternary period, then the default activity has been termed as active fault, if we were within 10,000 years and beyond that up to say, 1.6 or maybe 1.8 million years, then we are talking about the potential active fault and further down is inactive.

Now, this inactive; how far this is considerable, we will discuss this when we are coming to the individual topics that what we have identified that some of the potential faults which might not have shown the activity in last 5,000 years have become active in present day, okay.

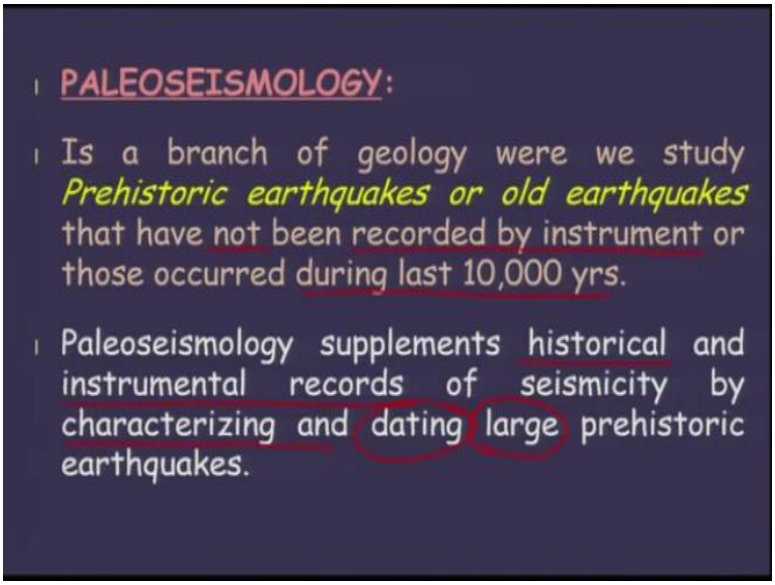
(Refer Slide Time: 02:14)



So, moving further in this part, this is the same but this is more detail about all the geological timescale, era period and epoch we are having here, so for us this is the important part, that is if you are talking about either 1.6 or 1.8 so, in some literature you will find this as in 2 million years and some literature you will find is 1.8 and the most youngest one that is the most youngest epoch is your 10,000 years that is your Holocene.

So, basically what we are going to look at is the youngest or the most youngest landforms and the sediment succession to identify the signatures of the earthquakes.

(Refer Slide Time: 03:11)



Now, coming down to paleoseismology part, if you look at, then we have the paleoseismology basically, is a part of the geology or earth sciences, so as a definition if you take paleoseismology is a branch of geology where we study prehistoric earthquakes or we can say ancient earthquakes or old earthquakes that have not been recorded by instrument or those occurred during last 10,000 years, so not been recorded by instruments.

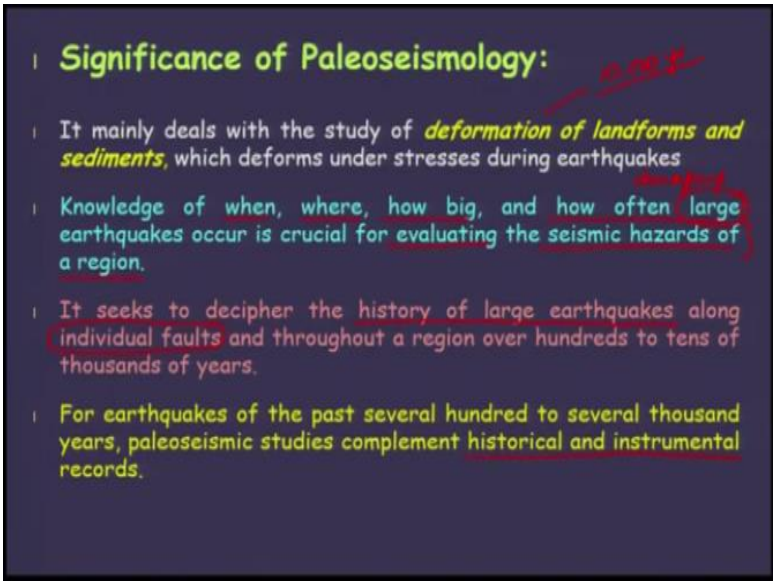
Because this is again we are talking about only before the invention of the instruments which started recording the earthquakes mainly, the seismic meters and all that and further more older if you want, you can go up to 10,000 years so, this branch of geology that is paleoseismology supplements historical and instrumental records of seismicity by characterizing and dating large prehistoric earthquakes.

So, if all the data is available and the historical chronicles or they have been also recorded by the instruments so basically, it tries to complement and it helps in characterizing the events, okay. So, dating part is what you are talking about that if you have the ages, we can bracket the events and we can at least be able to tell that when those earthquakes took place on a particular fault.

So and as I have been emphasizing right from the beginning that we are interested it in the large earthquakes so, if you refer one of this slide of the previous lecture where we have discussed about the rupture areas or the rupture length, then up to 5 magnitude, no evidence you will be able to see but above 5 magnitude earthquakes, you will be able to look at or there may be a displacement and which varies, okay.

For example, 9.5 magnitude, the rupture may extend up to 1000 kilometres, so mostly we are concerned about the large (()) (06:01) because a large amount of energy will be released and they would be more damaging in terms of the hazard.

(Refer Slide Time: 06:10)



So, significance briefly, I just told about that we need to have the complete database of the earthquakes which were recorded by the instrument or which were unrecorded by the instrument and which the data is available in the historical chronicles or maybe they have been missed out because of some or the other regions, so significance of paleoseismology is basically, it mainly deals with the study of deformation of landforms and sediments.

And again we will say that okay, fine, sediments which are or the landforms which are about as old as 10,000 years, so up to 10,000 years will be more keen and so those landforms and the sediments deformed under stresses during the earthquake. The knowledge of when, where and how big and how often large earthquake occurs is crucial for evolution the seismic hazard of any given region.

So, this is one of the basic we can say, the motto of this studies that basically, we want to know that when, where, how big was the earthquake and how often such large magnitude damaging earthquakes have occurred and this will eventually, help in evaluating the seismic hazard of any given region. So, basically we are interested in seismic hazard assessment, so this data forms a very crucial parameter for the hazard assessment.

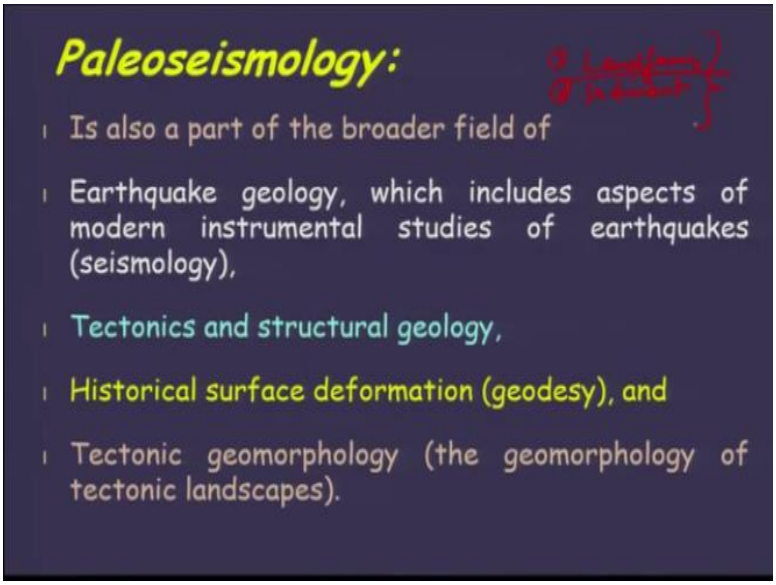
Further, it seeks to decipher the history of large earthquakes along individual or a particular fault and throughout a region over 100 to 10's of 1000's of years, so we are trying to reconstruct the history of large earthquakes and that also on individual faults. So, we are not talking about the regions in particular region, you may have number of faults okay, so number of active faults, those different faults will have different history of large earthquake.

So, this is again for example, if you are having several fault lines, so when this fault; fault A, B and C got activated and will responsible for triggering earthquakes, okay. So, they will probably not show the same time span of the occurrence of earthquake. So, suppose this earthquake has hosted an event in 1900 AD, this might have hosted an event in 1400 AD or so, so the time is different and when basially, we are talking about the recurrence how often, okay.

So, this is the part of the recurrence we are talking about so, when you know the characteristic of the individual faults, then you will be able to have better seismic hazard evaluation and further for earthquakes, the past several 1000 years to several 1000 years, paleoseismic studies complement historical and instrumental data. So, as I told in the; and this one of the point here on the top that we can complement the data which has been generated from the paleosiesmic study with the data which is available from historical and instrumental records.

So that also can help in a sense because during the historical times or even before if particularly, if we talk about the Indian subcontinent part or any other region in the world, the paleoseismology is not very old science and of that is the field of Earth Sciences because it has recently been evolved not around 1980 or so, so characterizing the individual fault and correlating those events where the historical data is going to be an extremely helpful part okay.

(Refer Slide Time: 11:31)

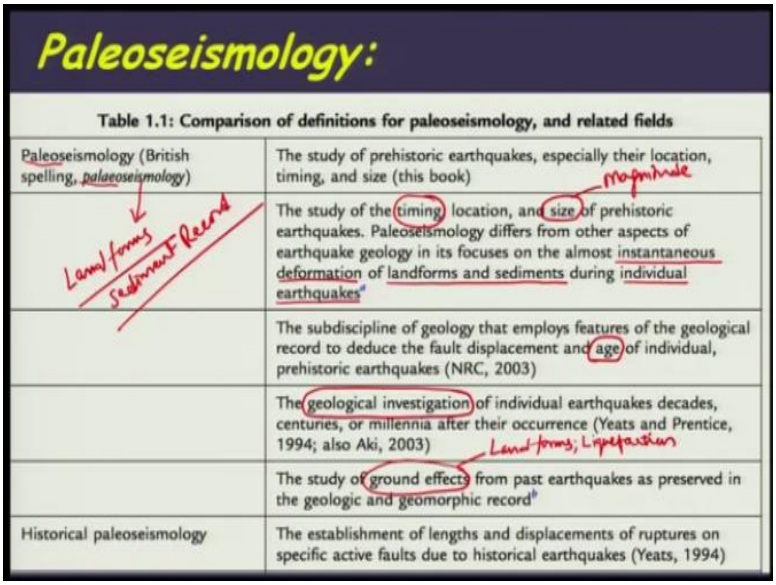


Now, paleoseismology also is also a part of broader fields of earthquake geology, which includes aspect of modern instrumental studies of earthquake that is seismology, tectonics and structural geology, historical surface deformation, geodesy and that what I was talking in the previous lecture that even the geodesy can be taken into consideration and the deformation pattern of the historical time can be compared with the on-going present deformation with the help of GPS.

Then it also deals with the tectonic geomorphology, the geomorphology of tectonic landscape, so there are broader fields which are also included, so you need to have the understanding of the structural geology in the sense here, okay and then detect on geomorphology part, so these are 2 important portions or the fields which are important and along with this, we also need to have the understanding of sedimentology part also.

Because we will be dealing with landforms and sediment succession, so these 2 needs to be understood well, okay.

(Refer Slide Time: 13:09)



So, there are few more references or maybe you can say the definition by different groups, which talks about the comparison of definition for paleosiesmology and related fields. So, paleosiesmology can be spelled either like this; paleo or you can say paleo, okay, so there is a and this may be another like British spelling this something where we have additional a here but both are correct okay, no issue for that.

So, it says that the study of prehistoric earthquakes especially talks about their location, timing and size and this definition is from the book of paleosiesmology by McCalpin and then second one, it talks about the study of timing, location and size of prehistoric earthquakes. Paleosiesmology differs from other aspects of earthquake geology when its focuses on the almost instantaneous deformation of the land form and the sediments during individual earthquake.

So, the paleosiesmology mainly focuses on the landforms and sediments, okay and where the area has gone under instantaneous deformation because of the individual or respective earth quakes, okay. Further definition is that it is the sub-discipline of geology that employs features of geological records to deduce for displacement and age of individual prehistoric earthquakes.

So, here this talks about again, almost similar that it talks about the individual age, okay, so when you say age, then you are talking about the timing of that particular event, then another definition has been given the geological investigation of individual earthquake deduced or

decades, earthquake decades, centuries or millennium after their occurrence, okay. So, for whatever the signatures are preserved in geological records.

So, geological records, if we seen in the broader sense but if we narrow down then we are talking about the landforms and the sediments, okay so those earthquakes which have occurred either 100 years ago or 1000 years ago or more, okay. Further the study of ground effect from past earthquake as preserved in the geologic or geomorphic records, so ground effects will be all related to your landforms.

Or you can say also, as I discuss very briefly but we will talk later that is the liquefaction, so mainly this will include your faults curves and displacement of the landforms that is the manifestation of the on-going deformation on the surface and you talk about the geologic science then we are talking about the landforms and the sediments. The historical paleosiesmology; the definition is that it helps establishment of lengths of displacement and displacement of ruptures on a specific fault due to historical earthquakes, okay.

And this has been given by Bob Yeats 1994, so there are several definitions for paleosiesmology and related field, so in short what we can say that there is the studies will include maybe in the next coming slides you will find those bullets mainly, we are focusing on landforms and sediments; sediment record and we are interested in knowing the timing, location and size; size will be your magnitude.

Because this whole exercise is going to help us in terms of you know, will reducing the hazard related to a particular earthquake or you can say the earthquake triggered or occurrence of earthquake on a particular fault. So, this is these are few examples of the different type of different definitions and comparison.

(Refer Slide Time: 18:35)

Paleoseismicity	Prehistoric earthquakes resulting in slip on faults (Engelder, 1974)[c]
Earthquake geology	In the broad sense, is the study of the history, effects, and mechanics of earthquakes within and on the Earth's crust. Most often, earthquake geology is synonymous with active tectonics, a term used to describe the study of tectonic movements that are expected to occur within a future time span of concern to society. Important aspects of earthquake geology include the study of tectonic landforms on the Earth's surface and folds and faults within its crust produced by many earthquakes over thousands to millions of years[d]
	... commonly regarded as synonymous with neotectonics (Yeats *et al.*, 1996, p.4)
Neotectonics	The study of the post-Miocene structures and structural history of the Earth's crust[c] Tertiary / Quaternary
Active tectonics	Tectonic movements that are expected to occur within a future time span of concern to society (Wallace, 1986). See book of the same title by Keller and Pinter (2002)
Morphotectonics	See tectonic geomorphology[c]
Seismotectonics	Study of the role of seismic activity in tectonics; includes examinations of the processes precursory to and accompanying earthquakes, the regionally significant geologic structures generated by earthquakes, and the temporal or spatial variations in processes or structures[c]

Then, further paleoseismicity, prehistoric earthquake resulting in slip on faults, then we have earthquake geology, neo tectonics, active tectonics, morphotectonics, seismotectonic, so earthquake geology in the broad sense is the study of the history effect and mechanism of earthquakes within the earth crust. So, I will not go into the detail of each and every part here but you can read out when you are having the notes.

But of course, the important portion here is that neo tectonics, then talking about the active tectonism, so the neo tectonics, the study of post Miocene, okay so, this we are talking about a tertiary period okay, so tertiary period the age or you can say at the transition of tertiary and quaternary. So, during the transition of this 2 period what about the studies or the structures we are talking about is been termed as the new tectonic activity.

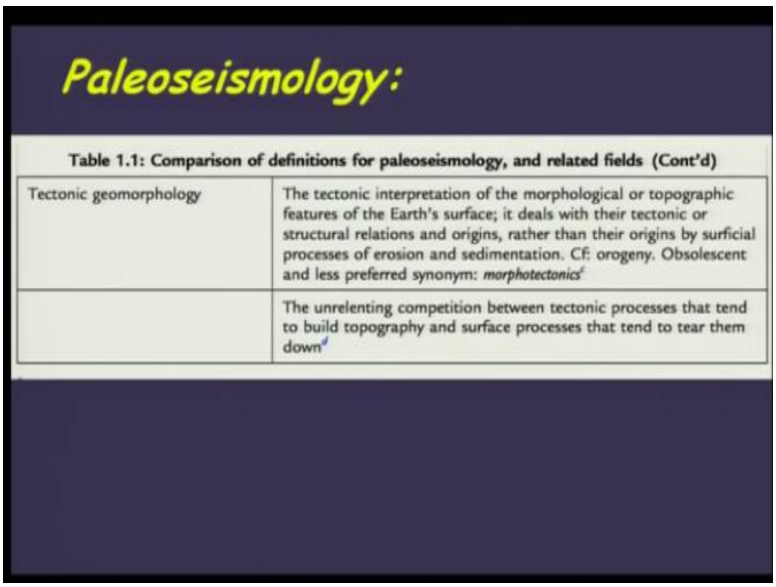
Active tectonics, tectonic moments that are expected to occur within a future time span of concern to the society, so this is the most important one for us, okay. So, the future time span of and it is concerned to the society, so this is most important for us in terms of doing when we are talking about the paleoseismology pattern. Morpho tectonic, again the tectonic geomorphology is the similarly, you can see because morphology of the surface okay.

We are talking about the morphology of the surface and those surfaces or the landforms which are generated because of the tectonic activity, so morpho tectonic basically confines to the tectonic geomorphology. Seismotectonic; study of the role of seismic activity in tectonics okay, so then you talk about mostly, the earthquake pattern and all that.

And in terms of that you also talk about the occurrence of the earthquakes either micro earthquakes we are talking about, small earthquakes and based on that, if you do the detail investigations, then you may pick up the precursor events, okay. So, this portion of siesmotectonic is the part where the seismologists are more involved and when they look the distribution of the seismic events or the earthquakes on a regional scale.

And whether they are telling something about their relevance with the geological structures and this geological structure could be your active defaults also, okay. So, basically we have a couple of definitions which we have seen here, which are in connection with the paleoseismology part, okay then further this is what we are talking about the Morpho tectonic.

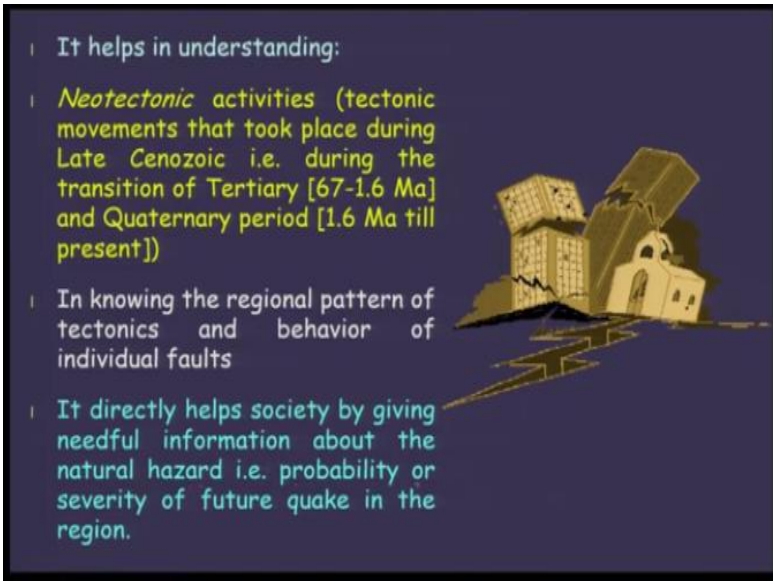
(Refer Slide Time: 22:21)



Next is the tectonic geomorphology; tectonic interpretation of morphological or topographical features of the Earth's surface, it deals with their tectonic and structural relations and origin, so those landforms which are been formed or generated by the on-going tectonic activity. So, on the larger scale if you take, you can come and you can talk about the origins and that is your Himalayan origin.

So, on the global scale, okay local scale and regional and the local scale, you can talk about the folds, faults and further what we are talking on the local scale what we do for the paleoseismological part, okay.

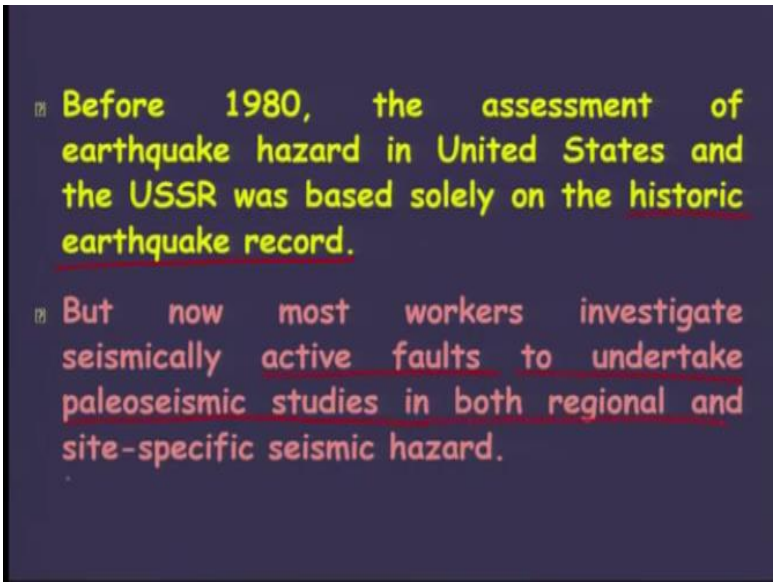
(Refer Slide Time: 23:10)



So, in a nutshell, the paleoseismology helps in understanding neo tectonic activity and that what I was talking about the tectonic activity that is neo tectonic activity is the moments that took place during late Cenozoic that is during the transition of tertiary and quaternary period that has been termed as; that activity has been termed as or defined as the new tectonic activities.

Further it helps in knowing the regional pattern of tectonics and the behaviour of individual fault, it directly helps society by giving needful information about the natural hazard and here the natural hazard what we are looking at geological hazard is your earthquakes and it helps and giving the idea about that probability or the severity of the future earthquake in a given area.

(Refer Slide Time: 24:16)



So, as I told that this field is quite young in the sense, okay of and not many regions have been explored and even in terms of the Indian subcontinent, we know that there are 3 major seismic zones or the vulnerable zones of the regions; one is Himalaya, Andaman and the east and west is macron zone and Kutch we are having in the West. So, this field started like before in 1980, the assessment of the earthquake hazard in United States and USSR was based solely on the historical earthquake records.

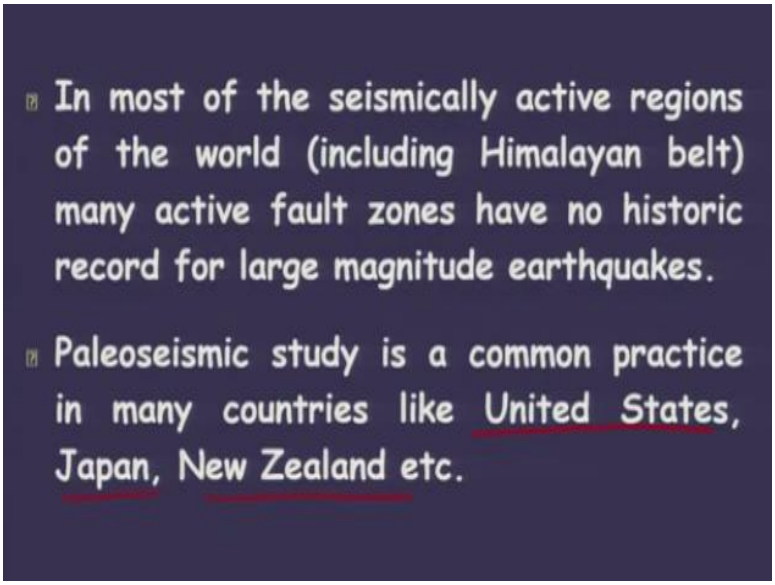
So, as I have been emphasizing that the one most important part which, on which the study should be started that paleoseismic studies is the historical record if at all we have that historical record but if you are not having then that will help us in reconstructing the past events. So, we mostly like the paleoseismology was initially they been initiated in the countries like US, Japan.

And then slowly, we are now also like last 2, 3 decades we have started in India, so before even 1980 in the countries like US and USSR, the hazard assessment was been done based on the historical data. So, for country like us suppose, we are not having the; if we have the historical records then at least we will be able to do the proper assessment but to some extent, if we are not having for example, okay the historical data is not available.

Then, it is difficult and we may undersized the oral hazard but now, most workers investigates seismically active faults, okay to understand paleosiesmics study or to undertake the paleosiesmic study in both regional and site-specific seismic hazard assessment. So, for example for the Indian part, we even do not have the complete active fault at last and of course, we are lacking in the historical data also.

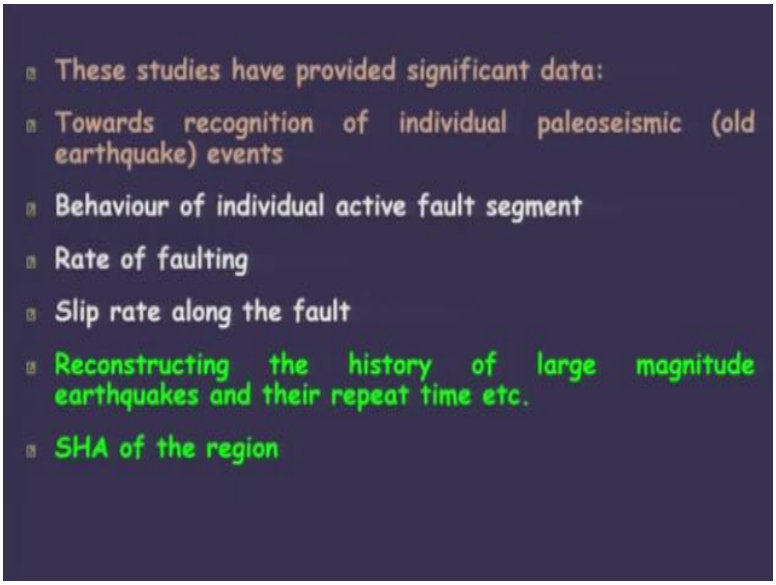
We do not have enough historical records to have the proper assessment, so for us paleoseismic studies either we are talking about on the regional scale or on the site-specific is extremely important.

(Refer Slide Time: 27:37)



In most of the seismically active regions of the world including Himalayan belt, many active fault zones have no historical records for large magnitude earthquakes and further the paleoseismic studies is one of the common practice, so in countries like United States, Japan, New Zealand, this is one of the common practice but in India this was not an common practice and still I would say that very few groups, research groups in India are doing this type of studies which is extremely, extremely important for the reduction of the life loss as well as property, okay.

(Refer Slide Time: 28:29)



Now, this studies have provided significant data towards recognition of individual paleosiesmic events on a particular given faults, behaviour of individual active fault segments, a rate of faulting, slip rate along the fault, reconstructing the history of large

magnitude earthquakes and their repeat time etc., so that is we are talking about the recurrence interval.

Then seismic hazard assessment of any region will be more easier okay, so these are few points which are important for the, this course which you should remember, so I will stop here and we will continue in the next lecture.