Geomorphology
Prof. Dr. Pitambar Pati
Department of Earth Science
Indian Institute of Technology Roorkee

Lecture-43
Tectonic Geomorphology

So, friends, good morning, welcome to this lecture series of geomorphology. So, today we will discuss about a new topic, it is called Tectonics Geomorphology. What does it mean, what is Tectonics Geomorphology? Here are 2 things to be understood here, the geomorphological processes is either it is fluvial process or a glacial process, eolian process or marine coastal processes.

Somehow they are influenced by tectonics faulting, folding and thrusting. So this tectonic processes mostly they influence the fluvial geomorphic processes, the river terraces are formed, the flood plains are widen a river get deepens this sedimentation production is more and sink area will be more. So that means by anyway this tectonic processes they are influencing the geomorphic processes, mainly the tectonically active regions.

For example, if you take this in Indian context, if you are talking, if you take in terms of Himalayan terrain, it is tectonically more active. That is why this geomorphic processes they frequently modify their position. The geomorphic processes they frequently modify these land surfaces, this sedimentation process, the river morphology like that, but if you go to this peninsular system, it is tectonically more stable that is hardly the tectonic process it influence the geomorphic process.

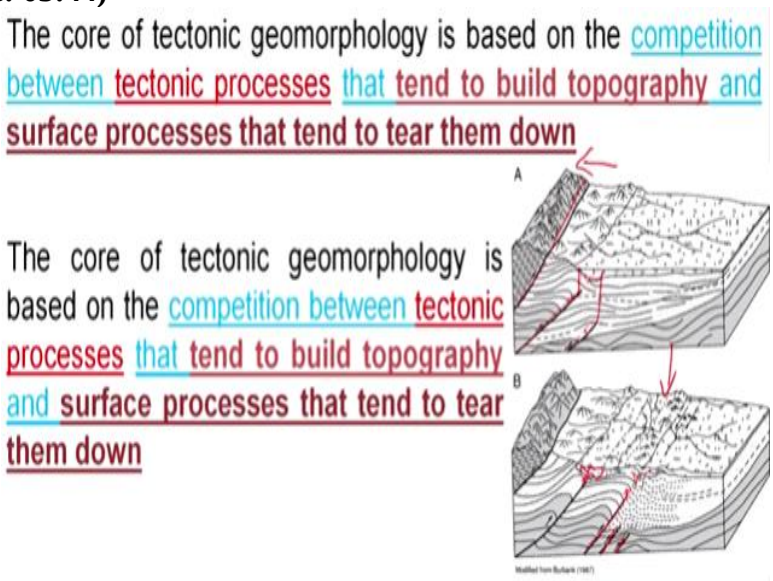
but one thing is to be understood here, one is the process and other is the response. For example, a fault which was formed a million years scale, million years time scale back so, suppose for example of 1 meter, throw that 1 meter throw it is if it is in a tectonically active region like this Ganga plain like this Himalayas within and for this fluvial process is very intense.

Within a year or within a tens of years, it will peneplain this, that means this fault scarp will degrade and finally there will be a plane land, but this same 1 meter throw fault if it is occurring

in peninsular, India in the hard rock terrain it will be difficult for the geomorphic process to modify it to peneplain it within that time scale. So that means the response of the geomorphic system to that 1 meter throw of a fault is different in time scale is concerned.

So, that means process and response there are 2 different things and is to be understood here. So in this class, we will talk about this tectonics geomorphology how the tectonics is influences the geomorphic processes and how the geomorphic processes are readily modified by the tectonic processes we will discuss here.

(Refer Slide Time: 03:44)



So the core of this tectonics geomorphology is based on the competition between tectonic process that tend to build the topography and the surface processes, they tend to tear them down. So here the tussle between the tectonics and the geomorphic process, tectonic process is always want to make this topographic either it is positive topography or this negative topography and the geomorphic process always tried to make the surface of this earth peneplain.

If you know the Davis geomorphic cycle, here it can be applied that this tectonic process is one within a sudden within a small time scales some time limit a upliftment will be there and that uplifted part will be readily modified by the geomorphic process gradually and finally, it comes to the Monadnock states it will take long time to respond the geomorphic process to this tectonic activity so, that means, it is the tussle between these tectonic process and the geomorphic process.

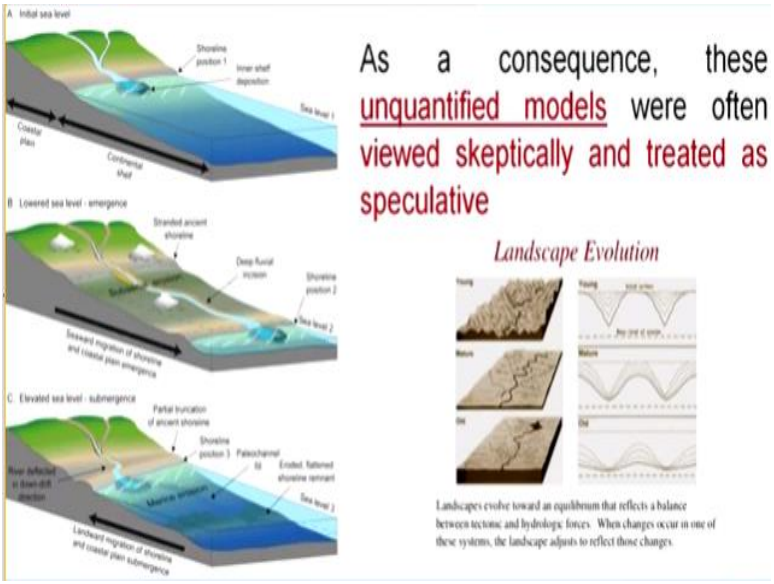
To modify the hard surface readily so, if you see this figure given below in this figure, if you see this is the thrust and here this is a blind thrust that means it is just buried or it is developing and not reached up to the surface. Similarly, another thrust which is south of this one, if it is north, so, it is south of this one again it is somewhat more depth as compared to this one.

But with time if you see here, this thrust has reached up to this and it is here it is influencing sediment similar this thrust had reached up to this and as influenced this surface sediment and here new thrust coming up. So, in this case if you see this surface geomorphic processes here, river is flowing, this is the piedmont area piedmont of this zone. Now you see this surface geomorphology it is affecting the fluvial process.

The piedmont development, the sediment migration likes other problems in the groundwater movement, like the other processes also they are influencing. So that I want to say, the tectonic process with time, the influence the geomorphic surface very effectively, the core of tectonics geomorphology is based on the competition between the tectonic process that tend to build the topography and the surficial process that to tear them down.

So the resultant is in front of us so within a million years time scale or the time window if you take the 1000's of years of time window within the time window, whatever the tectonic processes is there, what are the geomorphic processes is there so combinely they modified this earth surface and finally within the time window, where we are looking, the resultant modification modified version of this earth surface.

(Refer Slide Time: 07:01)



So as a consequence, this unquantified models are often viewed skeptically and treated them speculative, what are these unquantified model? You see there are many models has been prepared for this to, into by looking this interaction of the tectonic processes in geomorphic process, but with all these models, they are lack of or many of these models, they are lack of time constants so there is no time, time means rate.

What rate the process is working, what rate this sediment is eroding at, what rate the deposition is going on, what rate river is shifting its course, so at what rate the river valley is widening or deepening? So, that means this rate when we say the rate that means it is a quantified model. Because we can predict from this quantified model we can predict if you remember our earlier classes when we are talking about the geomorphological models.

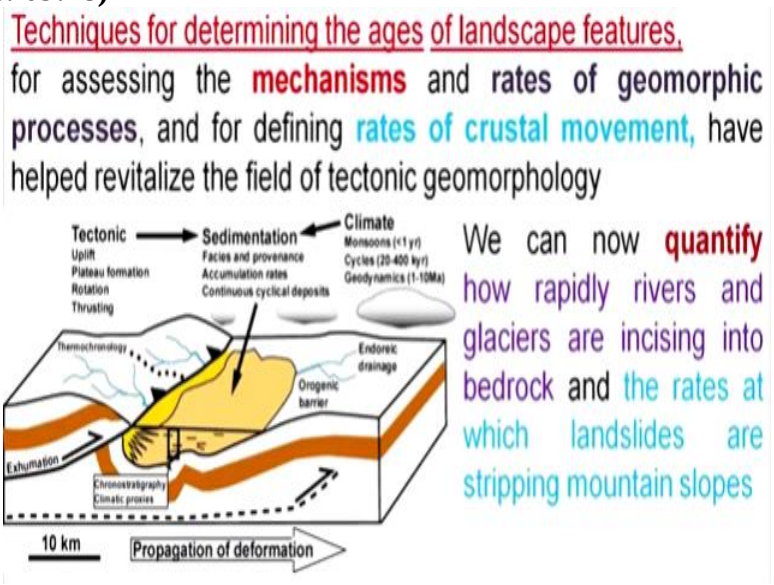
In this model, we would discuss that they reach a time frame which is required time frame, the time constants should be required, because we want to predict the future. So, if this rate of river erosion is going on, so, value will widen in this years or this river there will be flooded then this river will be flooded within this much area and this within the time so, that until unless this time constant is given until unless this time bracket is given.

So, these models whatever the models we prepare they are the unquantified models. So, in geological in the literature, there are models available, but most of these models are unquantified model because time scale is not given. So, to predict this geomorphic feature which can work

with futures so, the to predict that we need to times constants that will be quantified model so, if you see here, this young stage and this is mature stage this is old stage.

And this is the block diagram given here at what rate if we can calculate here this is the rate of river erosion, this is the rate of valley degradation. So, that means, we can predict with this timescale we will get a valley of this much size, we will get a valley of this much segment size so, that prediction is a quantified model.

(Refer Slide Time: 09:28)

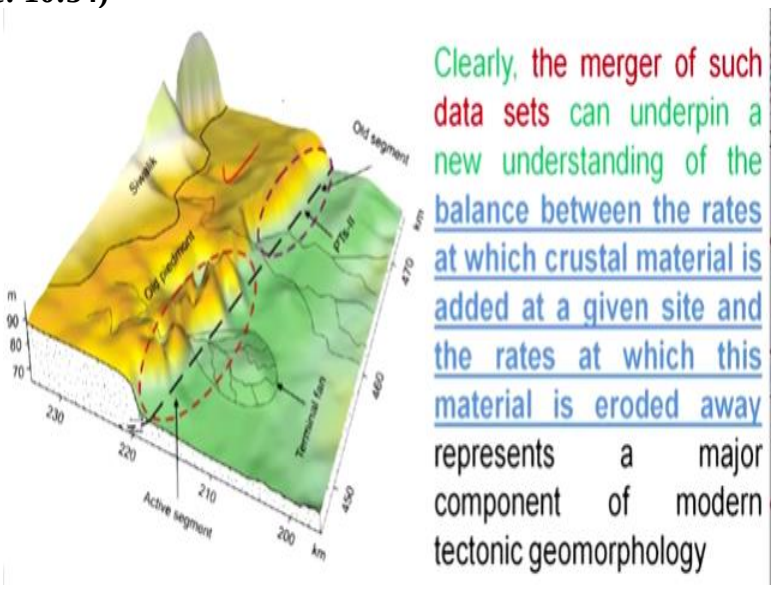


So, now, techniques for determining the age of landscape features are available for assessing the mechanism and rate of geomorphic processes and the defined rate of crustal movement have been helped revitalize the field of tectonic geomorphology. We have many dating techniques available, very precise dating techniques available but some dating techniques they are very useful for this geomorphological use.

But some of them are not for example if we are taking some Precambrian rocks to date it will some billion years plus minus some million that means million years scale is the error. But if we take this quaternary gives some 1000 years, some 100 of years is there, so that means in the geomorphic process, this geomorphic process within 100 of years within 1000 of years, so, that means within that error limit, we are bracketing this geomorphic process.

So, that means, what type of dating techniques we will use in geomorphological modeling. So, that is also important, we can now quantify how rapidly the rivers and glaciers are incising into bedrock and the rate at which the landscapes are stripping at mountain slopes so, those quantification it essential for predicting the future and preparing a quantified geomorphic model.

(Refer Slide Time: 10:54)



So, if you see here, this is the digital elevation model around the Himalayas you will see this is one thrust which is south of this Himalayan frontal thrust and it is in the Himalayan piedmont. So, now you see within that one thrust here if you see we are getting this red one, we are getting some of these eroded erosional topography. But as compared to these, these topographies near about smooth so that means it says even if we have 1 thrust, we need we have 1 fault.

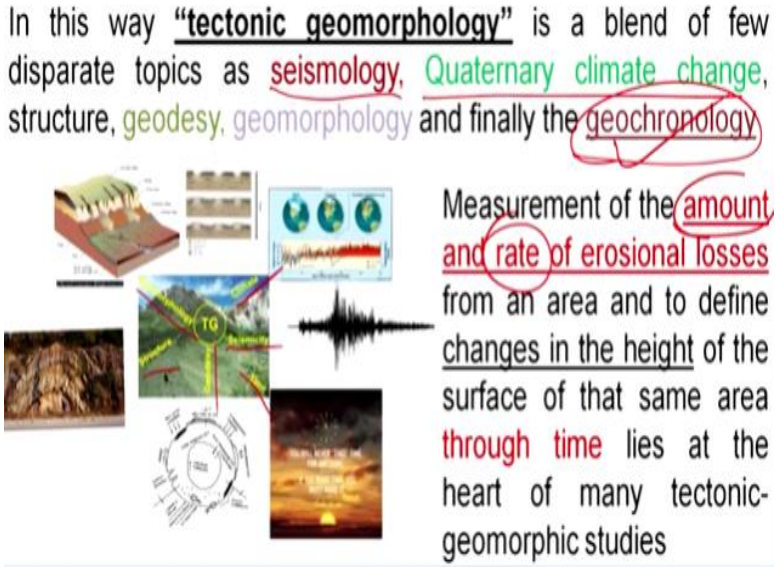
Or the whole fault or the whole thrust segment, it is not active throughout its length in a particular geological time or in a particular time. So, that means to predict this we need different types of models defferent types of constants and dependable parameters. So that is why this modeling in geomorphology and it is time specific modeling and time quantified modeling is important clearly the merger of such data sets can underpin a new understanding of the balance.

Between the rate of at which this crustal material is being added at the given site and the rate at which this material is eroded away represents a major component of modern tectonics geomorphology. So if you remember when ever talking about they say hill slopes types, 3 types

of hills slopes are their waxing slope, wanning slope and straight slope. So, this material added if it is more than the material removed, so that it will be a waxing or convex slope.

Similarly, this tectonics geomorphology it deals with the balancing budget between the material added by the tectonic forces and removal by this geomorphic process and what type of topography, it is going to build here in a specific site this is a fundamental understanding of tectonics geomorphology.

(Refer Slide Time: 13:10)



So in this way, these tectonics geomorphology is a blend of few desperate topics of like seismology, quaternary climate change, like structure, or rock structure is geodesy geomorphology and finally, the geochronology. So, geochronology, it is important here, because through the tectonics geomorphology, we want to understand the tectonic process and the geometry process and we want to predict the future until unless geochronology is depicted.

That means the rate is not known to us so that means prediction is impossible. So that is why geochronology it is very important in terms of quaternary geomorphology and what type of geochronology we will choose that depends upon what type of timescale we want to predict. So that is seismology, it is important because seismic processes that are the mostly the tectonic processes are seismic processes.

They influence the geomorphology then quaternary climate change that is also new important parameters in techniques geomorphology quaternary climate change. So, climate change in geological past even if it in quaternary we have experienced many times the climate changes the warm and humid when glacial, interglacial time. In glacial times, most of this water they are frigid and the sea level was much below this present level.

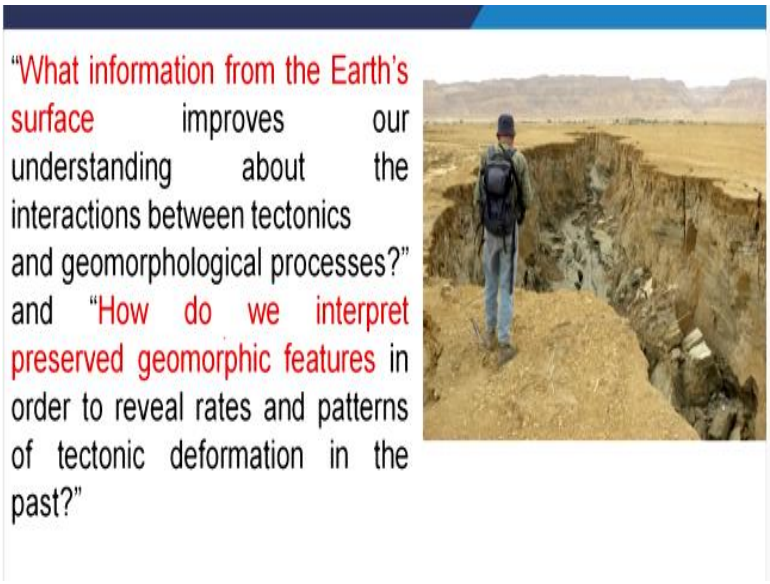
And there will be no more much sediment was available either the sediment was due to glacial actions. But in interglacial time there will be fluvial systems there are very active and finally, we are getting a system which is much more wider geomorphic variability as compared to this glacial systems. Similarly, this rock structures that also define what type of geomorphic features will either it is faulted terrain, it is jointed terrain, it is a folded terrain, it is dome-basins are there.

So, by looking geomorphic feature we can predict what type of structure also lies beneath to certain extent, then geodesy, it is the geophysics and how this gravity is working the how this gravity has responsible for this hill slope development for the material movement, the mass wasting, then geomorphology means the processes that fluvial process, glacial process, eolian process so, all these processes that work together.

So, this is geomorphology and finally, the geochronology so, measurement of this amount and rate of erosional losses here measurement the amount not only amount is important, the rate also important at what rate the erosion is going on? So amount and the rate of erosional losses from an area and to define change in height of the surface that same area through time lies at the heart of many tectonics geomorphology.

So, to what it particular site is choosed in that particular site, how much amount of material is added with time and how much material is being removed with the time that is measured, and this measurement has been shown in different ways, with the help of this climate with specificity with the time geodesy, structure, geomorphology all those things they contribute together in terms of tectonic geomorphology.

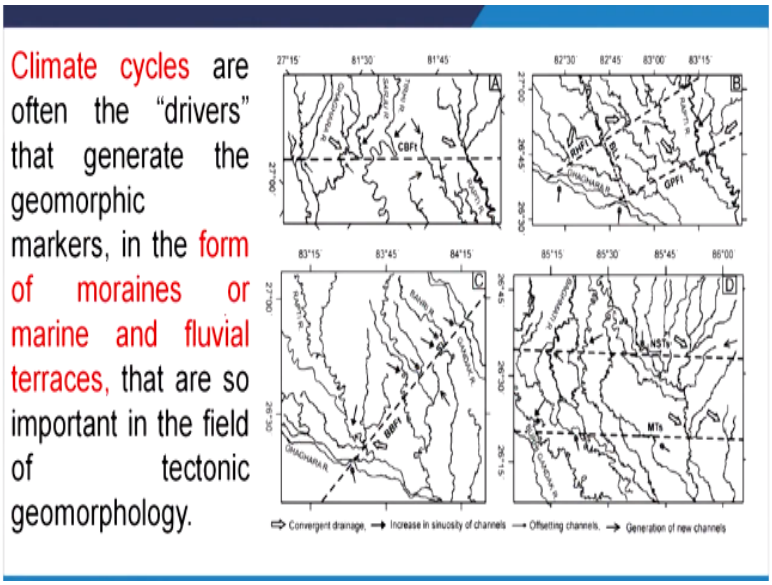
(Refer Slide Time: 16:33)



So what information from this earth surface improves our understanding about the interaction between the tectonics and the geomorphological processes and how do we interpret preserved the geomorphic features in order to reveals the rates and patterns of tectonic deformations in the past? So these are the 2 questions has to be answered in tectonics geomorphology one is by looking the past topography, the past geomorphological features.

We can unravel the what rate it was acting and the present day what is happening in front of us from which the rate of activities, the rate of geomorphic activities, we can retrieve. So that there has to be, there has to be compared whether this past activity and the present activity, they are going on at the same rate, or there is a change of the rate of formation or denotation of these processes that is one branch or one solution to this tectonic geomorphological activity studies.

(Refer Slide Time: 17:35)



Climate cycles are often the drivers that generate these geomorphic markers in the form of moraines or in the form of marine and fluvial terraces and that are so important in the field of tectonics geomorphology. These are the geomorphic markers here this is geomorphic marker, what are their geomorphic markers? Geomorphic marker, there are special types of geomorphic features that are specific to a particular type of tectonic activities.

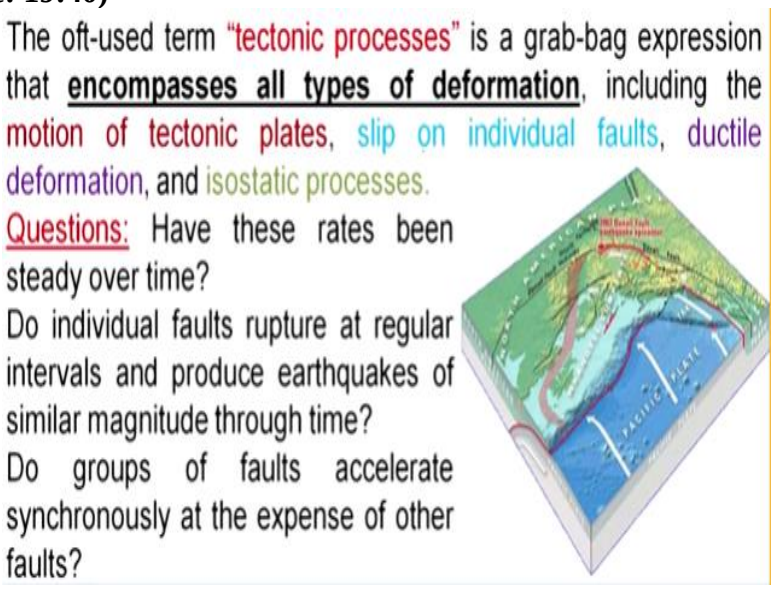
Or particular type of geomorphic activities for example, if you see here in this figure is given here the rivers, one rivers here second rivers, the third, fourth or do whatever this rivers if you see this line along this line, some of these points are there this rivers are converging some of the rivers they are getting high sinuosity, some of the river that are diverting or it is offset. Similarly, here along this line the river convergence is there is a river offset is there is a river sinuosity it is there similarly offset is there so these are interpreted as fault.

So this fault they are surface faults, they are influencing the geomorphic features or they are influencing the tectonic or the tectonic process, they are influencing the geomorphic features. So these are the geomorphic markers the river offset, the river convergence, the increase of sinuosity generation of new channels so these are the geomorphic markers. So similarly in Marine terraces in tectonic terraces, there are different geomorphic features.

The geomorphic markers are available so due to this geomorphic marker by help of this geomorphic marker, we can say what type of geotectonic process is going on either there is a

faulting way there is a terrace development is going on, or there is an there is a subsidence that is an upliftment like that so these geomorphic markers plays important role to define what type of tectonic features are going to happen or what type of tectonic features are there inside this sedimentary cover or within that rocks.

(Refer Slide Time: 19:40)



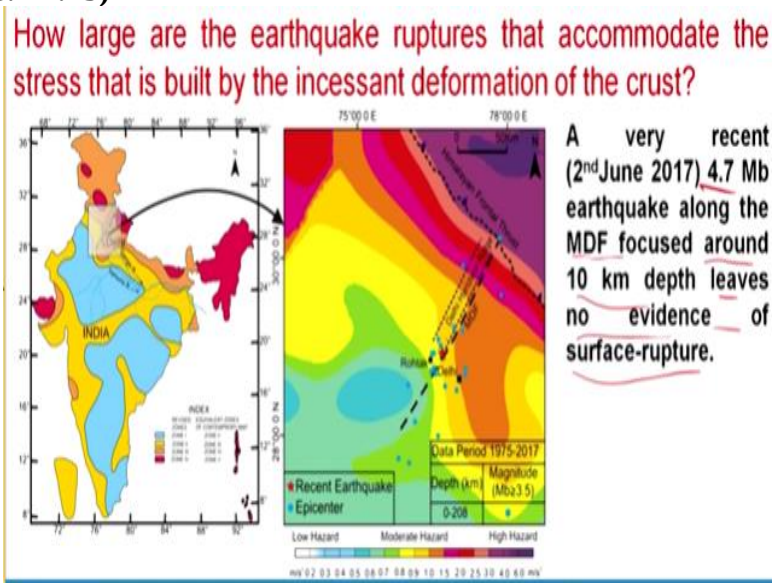
So they often use term tectonic process is a grab-bag expression that encompasses all type of deformation, including the motion of tectonic plates, slip of individual faults, ductile deformation and isostatic processes. So once we say it is a tectonic process that means all these type of activities associated with the deformation that is associated here. So now the question arises have these rates been steady or overtime.

So, this deformation suppose in fault is active, but it is activity is same throughout the geological past it is the geological time or do the individual faults rupture at regular intervals and produce earthquakes of similar magnitude throughout the time or do groups of faults accelerate synchronously and this expense of other faults so, these are these questions what type of tectonic terrain we are dealing with?

So, this type of accordingly will generate a number of questions and number of questions accordingly. So, what type of tectonic features we are dealing with, what type of tectonics geomorphic features we are dealing with, when which type of terrain we are dealing with? So, accordingly there are a number of questions to be asked and those questions will be answered

through the geomorphology process. The geomorphic rate of processes and the geo morphological features and that is an integral part or integrated together to define to explain the tectonics to geo morphological processes in that particular region.

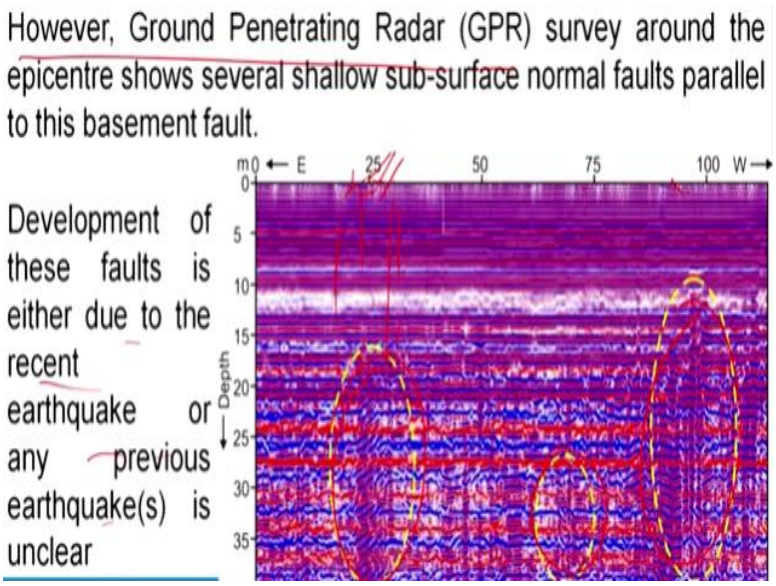
(Refer Slide Time: 21:15)



How another question is how large are these earthquake ruptures that accommodate the stress that built by these incessant deformation of this crust? So here then Indian example or Indian case studies very recent there is a earthquake come second June 2017 at 4.7 magnitude, it is called MDF focused around 10 kilometer depth leaves no evidence of surface rupture here. You see this is the Delhi Haridwar Ridge and this is the eastern part of this Delhi Haridwar Ridge. There is Mahendragarh-Dehradun Fault.

it is in 2017 2nd june there is earthquake 4.7 magnitude but near about this area near about this epicenter there was no surface rupture available. So, that does not mean the geomorphic process will not working there or geomorphic process will not be influenced there now, you see what is happening inside

(Refer Slide Time: 22:15)



Though there was no question of surface rupture, but there were, there was a subsurface evidence there are faults, and there are fractures within that. So, this Ground Penetrating Radar this is a ground penetrating radar profile, it says that, though there is no surface rapture of available, but surface faulting available, but the subsurface system, there are a number of fractures developed and now, the question arises if this system is in the subsurface, how this surface system will respond to this system, there is no response any particular timescale.

But with time, if these fractures will be there, there will be subsidence occur here through this fractures then the geomorphic processes are working on the surface they will respond. So, those subsurface features either it is shallow subsurface or deep subsurface they may or may not affect this geomorphic process in the surface in a particular time mode, but the same deformation same amount of deformation and with the geological future.

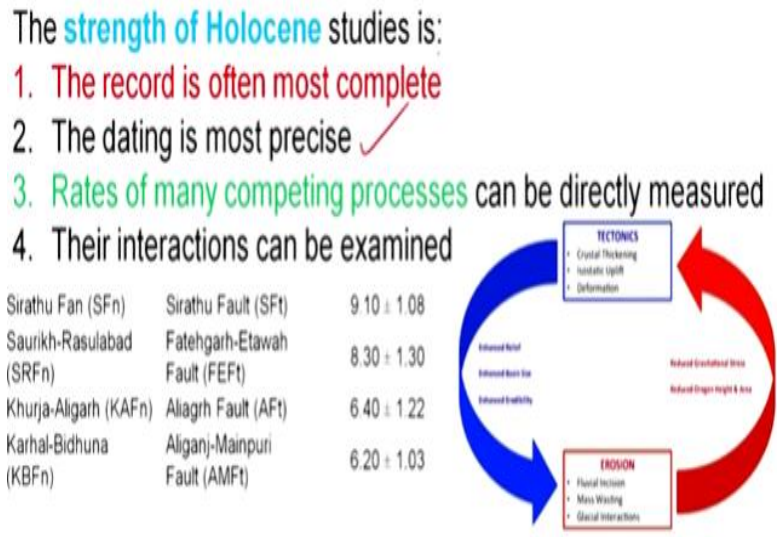
They may also affect this surficial process so, that affect this process and this effect, it may not immediately or may immediately so, depends upon the magnitude, if this process, if this subsidence occurred very close to this faulting activity then this surficial process will active together. So, if it is taking time some 100s of year even 10s of year even if it is year, then this surface geomorphic process will act or react accordingly.

So, development of these faults is either due to the recent earthquake or the previous earthquake. It is not clear here, but either this fault will be affected the surface geomorphic process or not

that depends upon how the subsurface processes or the how the subsurface structures that will grow and will reach near to the surface because surficial geomorphology is a surficial process, so, anything close to surface or anything on the surface that will affect the geomorphic process.

So, that depends upon whether this subsurface process to what extent they are influencing to the system so, the strength of this Holocene is there and there are some merits and demerits of the system.

(Refer Slide Time: 24:39)



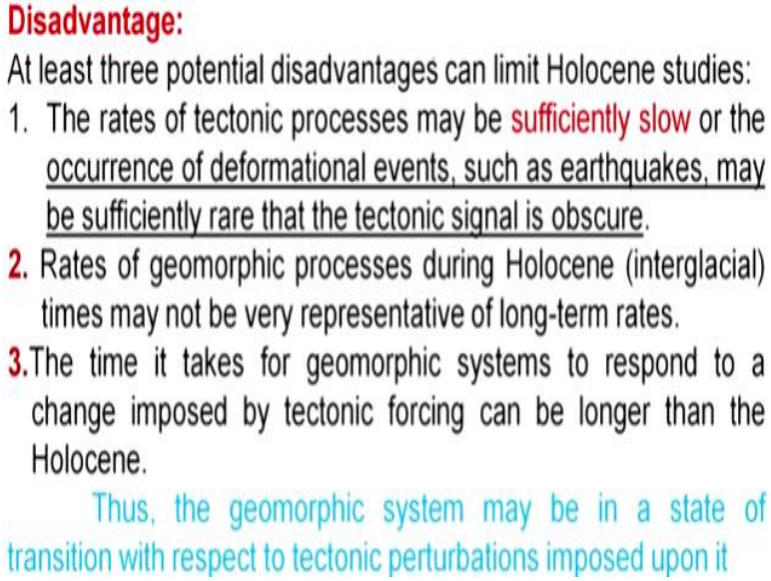
So strength of Holocene to study the geomorphic processes is there the record is often most complete, in the Holocene the record is most complete because we know these processes which are going on in front of us and dating is most precise, because as we have discussed earlier, in Precambrian rocks, once we are dating it is proposed for example, 570 million years plus minus 10 million years so 10 million is the error, but the geomorphic processes.

They are of this quaternaries they are within some 1000 of years some 100 of years to scale. So, in that error if we are putting this geomorphic process, it will be it is our foolishness. So that means geomorphic thats why dating, dating is most precise in quaternary in Holocene and that is why the one dating is precise that means the rate at what rate is working at the river is eroding at what rate eroding deposition is going on at what rate it is depositing.

So, that rate calculation of the rate is very precise then rates may completing process rates of many competing processes can be directly evaluated or measured. So, there are climatic change that are deposition that are erosion within that erosion there is fluvial erosion, eolian erosion, glacial erosion, so different contributing factors can be readily identified and different measurement for individual process can be calculated separately.

So, their interactions can be examined whether 1 is influencing the 2 or 3 is influencing 4, so different processes that means different individual processes either they are interacting with each other or not that can be calculated here so this is the strength of this Holocene and its some disadvantages also.

(Refer Slide Time: 26:27)



The rate of tectonic processes may be sufficiently slow or the occurrence of deformational events such as earthquakes may be sufficiently rare then the tectonic signals to be obscured. So here, this tectonic process, the rate of tectonic activity, the rate of tectonic process, maybe it is a slow process, as compared to this geomorphic process, the act of geomorphic process so that that means suppose one fault recurring event or the recurring occurrence frequency is about thousands of years.

So, within that 1000 year, the geomorphical process will modify the system so that means we cannot know that whether this tectonics is influencing the geomorphology or not. So the rates of geomorphic processes during Holocene or the interglacial time may not be very representative of

this long timescale. So whatever the geomorphical processes in our day, we are all calculating within the intercultural pillar 10,000 11,000 or 12,000 years back.

So it may not be reprinted the whole timescale so that meant, that means the rate of the geomorphic process, which is now a days going on may not they are working at the same rate in the geological past. So the time it takes for the geomorphic system to respond to a change imposed by the tectonic forces can be longer than the Holocene so here it is important. The Holocene is starting about 11 or 12,000 years back.

So that timescale is maybe not sufficient to this geomorphic system to respond for a particular tectonic event. So thus the geomorphic system may be in a state of transition with respect to tectonic attribution imposed on it. So these are some advantages are there some disadvantages there so this is all about this tectonic geomorphology and it can be surprised to hear this tectonics geomorphology is nothing it is the influence of tectonics on geomorphology.

And how the tectonic processes influences geomorphic process and how the geomorphic process is modifying the tectonic features together and the rate is important, the dating is important the precise dating now what is available so that the rate can be identified precisely calculated precisely so that we can predict through a geomorphic model, how this geological future or in this type of tectonic activity is going on.

What will be the landscape position, what will be the landscape modification, and where will be the habitable area not habitable area, where this river will flooded which river basin will be enclosed by the sea, which will above this sea level like that. So this is all about this tectonic geomorphology, I think we should stop here. Thank you very much.