Plate Tectonics
Prof. Pitambar Pati
Department of Earth Sciences
Indian Institute of Technology, Roorkee

Week - 11
Lecture – 55
Neotectonics- I

Okay friends, good morning and welcome to this class of plate tectonics. So, so far we are discussing that there are different plate boundaries, plates are moving, there are mineralization, there are hydrocarbon exploration purpose and there are societal need purpose, infrastructure development purpose and at many fields there are use of plate tectonics. And starting from this Hadean through Archean, Proterozoic and Mesozoic and now the plate tectonic process, it is a continuous process. That means starting from the beginning of this earth up to now this system is going on 24 into 7. And this geology, geomorphology and geophysics and every part of this earth it is responding to this movement in different ways. For example, the Himalayan development, this crustal and this mantle system it is taking part in this collisional system.

This upper surface, it is responding in terms of geomorphology, in terms of sedimentation, in terms of climate change. So, that means I want to say, whenever there is a tectonic process, the whole system starting from this mantle of this earth to the atmospheric level the whole system is being affected and those affect, it is recorded in different domains, starting from the rock domains to water domains, then in the vegetation, then in the atmospheric system. So, in isotopic records and that means I want to say, in many systems they respond to these tectonic processes. And today's topic is neotectonics.

So, neotectonics, the term itself is self-explanatory. This terminology, neo is associated with it. So, that means geologically, it is a new to this system. It is a newly devised, even newly derived terminology for this tectonic process which is ongoing. So, now the question arises, how would you distinguish this neotectonics from the paleotectonics because tectonic is a continuous process, starting from this Precambrian or this Hadean up to now.

So, where to put this boundary? That means in a geological time scale, if you see, there are different division and subdivisions where we will put this cap, yes, beyond this, it is called paleotectonics and above this we will say neotectonics. Suppose we are dividing a

boundary, yes, we put an arbitrary line, yes, this is the neotectonic domain and this is the paleotectonic domain. Now the question arises, if the neotectonic domain, whatever the tectonic activities is going on, is it affecting the paleotectonic systems? Is it superimposing or it is affecting whatever already been done by this paleotectonic is it affecting that? So, if it is superimposing with it, how would you distinguish, yes, this is done by neotectonic and this is done by paleotectonic. So that means there is some ambiguity, how to distinguish it? So let us discuss in elaborate way what is neotectonics.

So the neotectonics, the word, it is originated from the Greek word and its meaning is that the youngest, latest or ongoing crustal tectonics or this movement and its processes on this earth.

So, this is the youngest tectonic movement, youngest in the sense that means for example, suppose we are talking about geographical area. In geographical area, in this Indian context if I say the peninsula domain it was stabilized from this Archean-Proterozoic boundary. So after that no significant tectonic deformation has been recorded. So that means if I say it is the youngest tectonic movement, that means I have to go to this tectonic boundary. And coming to the Himalayan system, the youngest tectonic process, it is ongoing nowadays even if today when I am talking to you.

So that means how to distinguish when we are talking about the youngest one, that means it is varying from place to place. The youngest may be of a Precambrian age at some places and the youngest may be today at this moment for some places. So when we are talking about this time, that means again we are coming to an ambiguity to define a time process where to say or when to say it is young and it is old. Now the latest ongoing crustal tectonics, the latest ongoing tectonics, but in the Precambrian time if you go to this peninsular system, no tectonic movement, that means though this plate is moving, but however it is not responding that means to this tectonic process because no deformation has been recorded. Because this tectonic deformation is mostly confined to the plate boundaries.

So that means it is the latest or ongoing crustal tectonics movement processes on this earth, that is the largest tectonic process in the geological history. So that means in the geological history starting from the beginning of this earth up to now, if I want to put the neotectonics from this paleotectonic domain, so I am getting difficulties where to put this boundary because of its definition as it says. The term neo tectonics was introduced to geology by a Russian geologist in 1948 that is Obruchev and this was the first time introduced this neotectonic terminology. And here if you see this geological time scale, we have this neogene period and we have this quaternary period. So basically it says, it

originally refers to the most recent crustal movement of this earth from the end of neogene to the first half of quaternary.

If I say to the end of neogene, if you see this geological time scale, we have this neogene period which is ending at 2.58 million years, it is the boundary between the neogene and quaternary. So quaternary begins at 2.58 million years and neogene ends at 2.58 million years.

So as per definition if I am putting this boundary in terms of chronology, it says it is the end of neogene to the first half of quaternary, first half of quaternary I can say up to suppose for example here. So that means here up to this I can say this is the domain of this neotectonic field. So that means I can say up to around 1.5 million years. So now the question arises if I am putting this boundary here, but the most recent it is also nowadays happening.

So how can I distinguish that the recent tectonics which is going on, how can I define this? Is it is coming under this neotectonic domain? Is not it? So that means both time wise I have some ambiguity to define, place wise I have some ambiguity to distinguish, somewhere it is going for Precambrian domain, somewhere it is recent one, is not it? So that means by and large we can say there is an ambiguity with this definition when and where we have to put this neotectonic as it is defined by these workers. So there are number of people who are working or who have worked in this neotectonic domain, they have defined according to their that means some field and some their understanding. So according to this Pavlides, it is 1989, neo tectonics is the study of young tectonic event which have occurred or are still occurring in a given region after final orogeny or more precisely after the last significant tectonic reorganization. Now coming to another definition, it is the final orogeny or more precisely after the last significant tectonic reorganization. So last significant tectonic reorganization, if I compare different part of this world, it is different.

For example, this peninsular domain is different, it is the Archean-Proterozoic boundary, it is the last tectonic or last major or last significant tectonic reorganization occurred there. But in Himalayan today it is going on, so this latest tectonic reorganization it is going on now, is not it? So similarly Stewart 2005, it defined neo tectonic as the study of horizontal and vertical crustal movement that have occurred in geologically recent past and which may be ongoing today. So geologic recent past and which may be ongoing today, so that means both going present day as well as recent part tectonic event, all these can be categorized under neotectonic. So, basically the first definition also says it is the that means occur and still occurring in a given region. So

that means present day whatever the tectonic activity is going on and the last that means or you can say when it started all these comes under neotectonic definition.

So that means this latest tectonic event which was started for around some millions years back and it is continuing nowadays also, so all these they are coming under the neotectonic domain. So that means suppose for example we are going to the Himalayan tent now and there are number of earthquakes are occurring, so they are also coming under neotectonics. Though by definition it says the end of the neo gene and this first half of the quaternary this earlier definition it says, but still this present day tectonics which is going on nowadays by latest definition we can include those in this neotectonics domain. So that means you can see that means gradually the things are getting clear that this tectonic event which was started very recently and it is still ongoing, so we can categorize them under neotectonics domain. So it is the tectonic responsible for modern stress and strain condition.

So what about the stress and strain condition which is building up now, so the tectonics is responsible for that and the neotectonics should over print the paleotectonic evidence. It is obvious when there is some tectonic event was there and now this system is stabilized and later again this area is undergoing tectonic deformation. It is obvious that the newly formed tectonic structures that will overprint the earlier one, so there is no doubt on that. For example if you see here this is the Indian plate and at the northern boundary and you see there are number of basement faults which are originating from this peninsular India and it is going and some of them are cross-cutting to the Himalayas. So some of these faults they were earlier existing before this onset of this Himalayas and some of these faults they developed in response to this India-Asia collision.

So now the question arises even the earlier one or the recently developed that means recently in terms of I am talking about the India-Asia collision around 55 Ma back. So all these faults they are reorienting themselves they are responding to this present day ongoing collisional setting. So that means though these faults were around 55 million years back or even if the Precambrian time when they are existing but they are responding at the present day. So that means that is coming under neotectonics. Though the faults are much much much older than this age defined by this neotectonic definition but still they will come under neotectonics because they are reactivating at this time.

Is not it? So that means this paleotectonic features or paleotectonic structures they are overprinted by the newly developed structure or newly developed stress systems. So due to the development of the stress field in the Himalayan region this earlier existing faults

they are reorienting reorganizing themselves. So that is also coming under neotectonics domain. So the ambiguity with the definition. Two questions arise from these definitions that when exactly this neotectonic activity starts and is it really possible to make a distinction between old and recent tectonics? Obviously no.

For example these are the faults and some faults that already we have discussed they are existing from this Precambrian time. So their activity was some there some product was there and the present day these faults are undergoing this or responding to the Himalayan tectonics and their deformation is there. So can we distinguish that this is the older deformation product and younger deformation product through certain extent we can by dating techniques but in many cases we cannot. The age of commencement as specified by different scientists for this neotectonics vary widely. Then this gentleman fixed the age of commencement of neotectonics at early Neogene.

Then Gary et al 1972 that assigned the Pliocene which was subsequently supported by Bates and Jackson 1980. Then Bloom 1998 assumed Neogene at the starting age of neotectonics. Then Vita-Finzi 1986 attributed to Letts energy. Then that is Diebold and Muller 1985 assigned the neotectonics to this Quaternary epoch only. So that means different workers working in this neotectonic field they are assigning this time boundary differently.

So that means obviously there is an ambiguity in terms of chronologies associated. Therefore it appears that there is a lack of consciousness among the scientists regarding the actual period of neotectonic activity. As it is really tough to separate neotectonics from paleotectonics in the field observations. It is very difficult out in laboratory we can distinguish based on the dating techniques or so but otherwise in the field it is very difficult to identify or distinguish which feature actually neotectonic product and which one is the paleotectonic product. So as a result the later definition describe the neotectonics in a relative time frame such as the neotectonics starts at the different time in different region.

As we have discussed that this different region the last tectonic activity was or it was closed at different time frame. At the newer tectonic imprint which were started at different time intervals at a different geographical region. So that is why different region neotectonics is different. Now this question arises if some ambiguity is there or many ambiguities there both in terms of time and space then why do we need to study this neotectonic. So is it so important? So the question and these answers are very clear yes it is important and the first and the foremost importance is the societal need.

It is the neotectonic studies are important to provide evidence of locations of this major earthquakes along the active fault zone in the world. So here comes this actual requirement it is the locating the major earthquake zones and we know this earthquake zones they are fault zones. So that means identifying or mapping the active fault zones in the world it is the foremost important of neotectonics. For example here you see this is the American example of San Andreas fault which is active since many millions of years and it is nowadays also it is working and it is very active. So in Indian context if you see every fortnight or every month interval we are filling these tremors around billions here.

So here if you see this is the different faults they are passing through this Ganga plain and it is going to this Himalayas. So this identifying the active fault zones that is very important because of this societal need to predict or to demarcate yes these are the region where that is high earthquake-prone is there. So there are different faults like Mahedragarh-Dehradun fault, Delhi-Haridwar ridge then the great boundary fault, East Patna fault, West Patna fault that means there are number of faults that are passing through the populated area or you can say most of these populations they are confined in this plain area and below that there are active faults which are passing. Similarly there are active fault which is passing in the Himalayan and we have major mega structures like dams and tunnels like that. Similarly the coastal plane we have different fault systems and we are going to establish that is the ports, the defense establishment, then oil refineries like the mega structures are SEZ, special economic zone, smart cities like that.

So that means it is the need of this hour that this fault zones has to be mapped precisely and their activity whether they are presently active or their past activity whether it is following any cyclicity that is to be followed. So that is the societal need of neo-tectonics. And therefore, neotectonics and earthquake predictions are intimately associated subjects important for scientists and people living in this area where earthquake have occurred in the past and likely to occur in future that we have already discussed and if you see this is a pioneering work by Bilham and Wallace in 2005. You see this Indian subcontinent particularly the northern region that has been population density has been calculated and you can say this is Ten million, this is Delhi and these are the different places of India where the populations are shown in terms of size of the circle and this is the Himalayan arc and where the potential slip rate is given and these are the different fault systems they are passing through this northern edge of this Indian plate and it is you can say in this figure there are different faults, the same faults here it is there and this part of this Ganga plain or the Ganga basin it is highly populous. Now the question arises if a major earthquake is happening along some of these faults, so how much people will be affected, how much infrastructure damage will be there.

So that means it is the need of this hour we have to identify this fault zone if an earthquake occurs at particular fault then how much area will be damaged. So that means the last year we visited Moradabad, here is Moradabad fault is there and this is the basement fault and though it is lying around 5 kilometer below the surface but still it is active and its active nature it can be distinguished along the buildings around Moradabad there are number of buildings along this fault zone and which are within structure whether damage cracks are there. So that means though this fault is lying 5 kilometer below or 4 kilometer below but still it is active and its activities can well be distinguished along this infrastructure damage in the infrastructure. So that means identifying the fault zone it is very much essential for this growing population for the safety of this growing population. So that is why number of fault systems they are passing through the earth and that is why earthquake prediction and this active fault mapping these are the need of this hour for our infrastructure development and it is for the societal need.

Then if I go back to geological past and to present there are different manners or different techniques that people are using to study the neotectonic activities and particularly the fault activities and if I am going to 10 to the power 6 years back. So what people are using this neotectonic evidences, neotectonic evidences that means whatever the geological evidences are available for example river terraces that means that a fluvial geomorphological mapping and some other methods are also there. So this fault activity, last fault activity, geomorphic markers, terminal fans like that people are using and with subsequent decrease or if you are coming to modern days. So here you can say this instrumental record now is faults are being monitored through instruments for example the San Andres fault in America. It is instrumented, its rate of movement has been monitored.

Similarly in Himalayan terrain many of these faults or many of these regions have been instrumented and this rate of movement, the rate of convergence, rate of upliftment has been recorded. So that means gradually when we are coming from this past to present the preciseness of this precision of recording this tectonic activity or neotectonic activity is increasing. So earlier people are using the neotectonic evidences gradually with time that paleo-earthquake evidences, then archaeological evidences, then historical evidences, then instrumental now it is high quality instruments. So gradually the precision increases. And here some of these faults in this Ganga plain, here this list of faults are there and their activity or the last activity you can say this last activity it is been dated.

So we have dating techniques, there are number of dating techniques in the quaternary we are using and this last activity can be dated. So if a fault it can be dated for its number

of activities and these age or these gaps can be taken for study if it is occurring or if it is activating at a cyclic manner or it is not. So that means temporal behavior of these faults can be studied or can be monitored through two types of dating techniques. And as I was talking few minutes back the GPS systems in the Himalayas, so it is showing how these plates are moving, what is the direction, what is the rate of movement. For example, this scale is given here, this length it is indicating 45 millimeter per year.

So similarly according to the scale which part of this Himalayan system or which part of this Indian system it is moving in which direction and what is the rate of movement that can be detected. So another is the paleotectonics that mean neotectonics study it is by seismites. You can see these are the seismites structures and this is the fault that is the Moradabad fault as few minutes back I was talking. So along this Moradabad fault or around the Moradabad fault due to this fault activity the seismites are developed and these are nothing the deformation structures in the soft-sediments and that can be dated. So, the seismites can be dated to determine when this fault was activated to create the seismites.

So, through this fault if there are number of generations of seismites we can get, so we can say what is the age of formation or when the age of this activity of this fault. Then infrastructure development, dam, we have different dams in the Himalayan terrain and number of parts of India. So whether they are falling under active fault, whether this region around this dam it is undergoing any tectonic activity, any movement, any sub sediments, any upliftment that must be studied because it is that means larger economical project. So larger economy is associated with it. Similarly tunnel, suppose we are establishing a tunnel within this tectonic active zone without studying this neotectonic activity in that region and suddenly a earthquake comes and it happens like this.

So here this is the last latest image by Turkey earthquake you can say how this railway line is damaged. So now had it been happened in subsurface, suppose there is a tunnel which was passing and now this system is due to faulting this tunnel that means it is separating from this other part. So that means it would be a major damage. So that means this tunnel development, then oil refinery because all these listed here they are the mega architectural projects. So before spending crores of rupees or millions of dollar here we must study this tectonic around this and that is why if we satisfy yes this area is tectonically relatively stable then we can go for this type of that mean establishment.

Otherwise it is a second it is a matter of second or minute the whole system will go to the dam. So similarly we have seaport and port, airport development, then flood control structure, defense establishment, coastal area management and seismic proof structures. So either we need a seismic-proof structure in a particular area or we do not need. So

that depends upon the seismic activity of this area. For example in the northern India we are residing in a tectonic active zone close to the Himalayas so this seismic-proof structure it is very much an essential in this area.

Then needed research, if the research field the latest crustal tectonic traces that is fault and fold and their evolution that can be studied here. And it is development and evolution of present tectonic geomorphology that is mountain upliftment, basin lifting, river basin evolution that can be river management that can be studied through neotectonic activities. Then earthquake studies that can be studied that means this neotectonics can be studied through earthquakes. And here is a very interesting image about this Mahendagarh-Dehradun fault and you see this are the locations this black dots that indicate historical civilization sites. And now see the historical civilization site if you are joining they are joining through linear structure that means these are the paleochannels.

So traces of paleochannels. So now you see all these channels they are terminating at a particular line and this line is following this MDF or this Mahendagarh-Dehradun fault. And if you imagine during this Mahendagarh-Dehradun fault when these channels were diverted or it was totally dried up so about this civilization. So no water was there. So that means this civilization which that means villages or whatever this establishment were they must have migrated. So that means this historical or this pre-historical or the geological time scale if you see this major migration from this river basin or to away from the river basin one river basin to another river basin there are two regions are responsible one is climate another is tectonics.

So that is why neotectonic study not only for the research if the present day societal use demands highly to the study of neotectonics. And the modern and dynamic mechanism of the largest block movement that is active tectonics framework and the stress field. So how the stress field in the Himalayan system or the Ganga plain it is expressed here. Then volcano and geothermal resource. We have different volcanoes in India also and throughout the world.

So studying whether this volcano is likely to active or not active that can be studied through the neotectonics and this geothermal resource now you can see there are different geothermal sites in India and here it is falling under this Namada-Son-Damodar rift and this is the Mahanadi rift, this is the Godavari rift. So that means you see all these rift basins that means tectonically active regions they are source for these geothermal energy. Similarly this Puga, Manikaran and this other places in the Himalayan they are also tectonically active regions. So their energy resource is associated with tectonics mineral

resource associated with tectonics then hydrocarbon resource associated tectonics societal need it is associated tectonics. So that means tectonics it is in huge use that can be explored with time.

So thank you very much we will meet in the next class.