Plate Tectonics

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Week - 11
Lecture – 54
Indian Seismicity

So, friends, welcome to this class of plate tectonics. And today we are going to discuss about Indian seismicity, what does it mean to you? So, India we know it is a robust lithospheric system which is intruding into the Eurasian system and this collision started around 55 Ma and the western part of it is somehow older and the eastern part somehow it is younger. And most of these earthquakes in India, if you see this earthquakes distribution most of them they are lying at the boundary of this Indian subcontinent and very few they are inside and they are they can be termed as the intraplate earthquakes like the Bhuj earthquake, however, some of these earthquakes here and here particularly this is following in the Narmada- Son Graben or the SONATA Graben and here this Delhi-Aravalli range some of these earthquakes are following. So, 95 or 99 percent of this earthquake they are following these plate boundary. So, that is why seismicity in India are mostly by its plate tectonic setting and less are intraplate origin. So, seismicity it is the plate tectonics reflection and Indian subcontinent particularly the seismicity is totally and totally you can say it is governed by the plate tectonics.

And the Indian subcontinent is highly vulnerable to devastating earthquakes and mainly because of this collisional tectonics. We have different historical earthquakes like 1905 earthquake, 1934 Bihar-Nepal earthquake, 1905 Kangara earthquake and 2001 Bhuj earthquake. So, there are number of earthquakes they are most devastating and that earthquakes are nothing due to this interaction of these plates which are this India and Eurasian are going for the last 55 Ma or so. And we know this convergence between these two plates that gave rise to the Himalayan mountain system we have discussed it many time during this collisional system and we don't need to discuss further it here.

However, if you see about 59 percent of this in land area of India is liable to seismic hazard damage and this is the distribution of the different seismic zones. This India is divided into 4 seismic zones like 2, 3, 4 and 5 and different color index as given here you see this zone V it is very high risk zone area liable to shaking intensity 9 and above. And it is the zone 4 high risk zone and zone 3 it is moderate risk zone and zone 2 is low risk zone. So, that means, the whole Indian system 59 percent or around 60 percent of this Indian subcontinent landmass it is under seismic hazard. So, let us talk further what exactly the origin of seismicity and why there are there are some uneven distribution and which area is seismically more active and how we determine it.

So, India has a varying degree of seismicity or regions ranging from the stable continental region that is some part of are stable and with strong that means, greater than 6 magnitude earthquake in the Himalayas and northeast India and Indo-Burmese Indian ocean region it is characterized by magnitude more than 7 and this great earthquake more than 8 and 9 or this mega earthquake you can say it is more than 9 that is at the plate boundary zone particularly. And 4 zones that we have already discussed zone 2 seismically less active, 3 moderately active and 4 highly active and zone 5 it is represent the highest seismicity in the Indian subcontinent. And not only this landward part if you see this Andaman islands that is also coming under zone 5 because that is the plate which is the Indian plate which is subducting under the Burmese arc. The major earthquakes that occurred along this Himalayan plate boundary and this national center for seismology in India it is the custodian for the seismological data and you can get this information from this website all these earthquake record of different magnitude, different place that date that can be found from this website and you can take it and you can model for this future prediction of this earthquakes. And you see these are this earthquake distribution of this Indian subcontinent and around and particularly the Himalayan region it is concentrating at this part.

Now the surface velocity field and seismicity of the Indian subcontinent. So, now the question arises how to measure it? We have to talk about the surface velocity field that means the Indian subcontinent it is moving. Now, how to determine whether it is moving and this is the velocity measurement. Nowadays the researchers they are using GPS system or GNSS systems to calculate the velocity field at different segments of this earth's crust. But this velocity fields though we are measuring nowadays it is going on for the last 50 Ma or so.

And due to this movement and continued convergence that these earthquakes are occurring and different time scales of the geological past that has recorded different rate of movement. In the last class we were talking about the Indian plate movement was different at this different geological time scale. And those movement at different rate that was also responsible for different magnitude earthquakes or different degree of deformation at spatially different segments of this Himalayan system. So, global positioning system or GPS measurement shows that the Indian plate is moving northeast at a rate of 35 to 38 millimeter per annum. So, now the question arises what this around 4 centimeter per year movement it will change the seismicity? Yes, it can.

So, this is the surficial movement and this 4 or this 3.5 or 4 centimeter per annum it will affect largely into the rock structure under the subsurface. And finally, this stress which is build up during this movement it is either absorbed by this rocks and it is different or it can be reflected in terms of their slips their movements. And the geodetic data suggests that the deformation within the Tibetan plateau and its margins absorb more than 90 percent of this relative motion. Relative motion we have already discussed at the initial part of this class and more than 90 percent or more relative movement it is absorbed by the southern end of this Tibetan plateau, southern margin of the Tibetan plateau between India and Eurasian plate with most centred on this 50 kilometer wide region of the southern Tibet.

So, most of this relative movement it is observed here. So, most of the relative movement is observed here. So, deformation is more intense and this movement around 4 centimeter per year it creates internal shortening of this plateau which is account for more than one-third of this total convergence and south of this Kunlun fault if you see this geological map in the south of this Kunlun fault here the surface velocity field shows that the Tibetan plateau is extruding eastward relative to both the Indian and Asian plate. Here you see most of these strike-slip faults and it is the sinister strike-slip faults are there. So, once this sinister strike-slip fault is there that can be well reflected here at the GPS movement this is the southern part of this Himalaya you see this GPS movement is towards northeast.

However, if you are reaching the Tibetan plateau at the southern boundary this movement is just changing its direction and you see this segment its movement is either eastward or it is southeastward. So, that means, through this faults the strike-slip fault. So, this part of this continent it is extruding from this active deformational front and it is going away from it and this is called the lateral escape. So, this motion where the slices of this crust moves laterally out of the way and it is away from this colliding plate system that is called lateral escape. And due to this lateral escape number of crustal-scale strike-slip faults has been developed.

And as a result what is happening now east of this plateau north China and south China are moving to the east and southeast rate around 2 to 8 millimeter per annum to 6 to 11 millimeter per annum relative to this stable Eurasian plate. So, that means, part of this system it is extruding from this active deformation front or the collisional front. So, as a result when there is movement there is either extrusion or there is a deformation there is a absorbs of stress that is a release of strain is there. So, that is why earthquake is very frequent along the Himalayan front and along the particularly the plate boundaries. So, this earthquake focal mechanism solutions that is compiled from 1976 to 2000 year and it says that the thrust faulting occur along both the northern, southern and eastern margin of the Tibetan plateau.

So, that is if you see this distribution of this focal mechanism solution focal mechanism solution if you remember when we were talking about this earlier classes we had a class on focal mechanism solution how to do it. So, here you see the beach ball diagram distribution it says most of these earthquakes they are of thrust fault origin. However few of them there you say that is normal fault origin and why it is normal fault origin that we have discussed in the earlier class also because this compressional related extension. So, once we are compressing in this way so, we have to extend perpendicular to that and extensional that means, it is providing or it is creating normal faults. So, that is why most of this fault that means, most of this earthquake distributed along this plate boundary it is of thrust fault origin and within that Himalayas thrust faulting is prevalent.

So, we have prominent thrusts like the MBT, MCT, MFT. So, this most of these earthquakes in this Himalayas they are of thrust fault-origin and south of this Himalayas we have intraplate earthquakes. So, like this we have intraplate earthquakes and some of these earthquakes they are related to this SONATA graben it is Son-Narmada-Tapi graben and some of these earthquakes that is related to this extension of the Aravalli ridge and some of them are purely intraplate earthquake like the Bhuj earthquake system. So, this south of this Himalayas intraplate earthquake and other geophysical evidence indicate this Indian plate is flexed and slides beneath the Himalayas where it moves northward during the large earthquakes. So, that means, we have this Indian plate which is subsiding down at the below the Himalayan system.

So, that is why we have different type that means, Indian plate which was just flexing down and we have this Himalayas MBT, MFT so, like that. So, this is the Indo-Gangetic plane. So, in this Indo-Gangetic plane if you move you will find this step-like appearance of these faults. So, that this flexed Indian lithosphere it is going down under the Himalayan system. And north of this Himalayas normal faulting and east-west extension is dominant.

So, we are talking about this development of this rift basins probably you can remember this rift basins are nothing the extensional basins and this extension is nothing it is the compression related extension. So, due to this development of the rift basin due to develop from the normal faults. So, if you are moving to north of this Himalayas that means, you are going away from this compressional zone particularly. So, you are getting this normal faulting or extensional tectonic is dominating here. And strike-slip fault that is dominant in the region around 1500 kilometer wide north of this Himalayas and extending eastward into Indo-China.

Here we have different strike-slip faults are there for which this part of this Tibetan system it is extruding from this active collisional front. So, that is why here this region it is mostly governed by the strike-slip faulting. And active strike-slip faulting occurs in the western Himalayan syntaxis also. So, here we have two syntaxis in the last class we are talking about. One is the eastern syntaxis and another is the western syntaxis.

So, active strike-slip faulting occur in the western Himalayan syntaxis as well as the eastern syntaxis in the Pakistan and Myanmar. So, here we have this eastern syntaxis and here we have western syntaxis. Both the syntaxis they are recording this strike-slip motion and this is the crustal-scale strike-slip faults are there. So, here in the geological map it can say in the western syntaxis here this is the strike-slip dominating and mostly if you see this is the sinistral strike-slip fault. However, at the eastern syntaxis here at the Myanmar you can record here the dextral strike-slip fault.

And as the Himalayan system is bounded by this two strike-slip fault and we have thrust in this side. So, that is why the south of the syntaxis in Pakistan movement along the north strike-slip fault or this north striking fault is dominantly sinistral and south of one in Myanmar is mostly dextral that we have already discussed. So, these opposite sense of motion on either side of this India are compatible with the northward penetration of this Indian subcontinent into the Eurasian system that we have already discussed when we were talking about indentation experiment which was carried out earlier. We have a rigid system and we are putting or we are forcing to penetrate into this weak system that is the Eurasian system. So, that is why this strike-slip motion here and this strike-slip motion here for example, here this can be well explained in this animated image.

So, here this is the strike-slip motion you can see western syntaxis and at this side also you can see this side this we have eastern syntaxis here. So, these two strike-slip motion that is that means, making this Indian subcontinent isolate and it is penetrating into the Eurasian system. So, that means, the Himalayan tectonics can be well explained with this combination of all these strike-slip motion and their sense of displacement. So, these observation indicate that the convergence between India and Eurasia is accommodated by combination of shortening, east-west extension, strike-slip faulting, lateral escape and clockwise rotations. And addition to that uplift of the higher elevations of this Tibetan plateau by Miocene time indicates that the significant vertical uplift occurred after the India collided with Asia.

So, that means, not only the strike-slip motion, not only this thrust motion it is accommodating this movement of this Indian and Eurasian. So, there will be rise of this plateau, rise of this mountain system to accommodate this movement. So, currently this Himalayas are uplifted rapidly at a rate between 0.5 to 4 millimeter per annum and it is experience very high rate of erosion along their southern flank. So, why it is at the southern flank that we have talking about this climate and this plate tectonics that is well explained there, but at currently this upliftment is between 0.5 to 4 millimeter per year and this upliftment is different at different segments of the Himalayas due to this locking system, due to this cemented system of this Himalayas.

So, this is all about this plate motion and this earthquake on the seismicity around this Indian plate. So, thank you very much, we will meet in the next class.