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

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Basic Assumption of Plate Tectonics

So, friends welcome to this class, Plate Tectonics. So far, what we have discussed, the different types of lithospheric plate, lithospheres and this oceanic lithosphere, the continental lithosphere and this configuration of the plate says this continental plate, it may or may not constitutes of entirely of continental. However, the oceanic plate it is of oceanic totally. And the plates they interact with each other either through divergent system, converging system or they are sliding past with each other. So, that means, we have developed a theory, How the plates should behave, what should be the magmatic nature. What should be the metamorphic nature and the boundary And what should be the mineralization type, whether it can create basins If it is basins, which type of plate will be responsible for which type of basin development or so.

So, that means, the plate tectonics theory that we have developed it is based on certain assumptions and these assumptions are very much essential to understand the plate tectonics and to explain the observed material or to explain the observed scenario with the what is happening along or beneath this earth system or beneath this continental system or oceanic system in the mantle system basically you can say. So, the theory of plate tectonics which describes the interaction of the lithospheric plate and the consequences of this interaction is based on several important assumptions. So, what is this assumption? The first and the foremost assumption it says the generation of new plate material occurs by seafloor spreading that is new oceanic lithosphere is generated along this active mid-oceanic ridge system. Very important to understand here that new oceanic lithosphere is generated.

So, that means, if you see here we have a magma chamber and this is the mid-oceanic ridge system and this magma is being supplied here and it is forming the oceanic lithosphere. That means, it is creating the crust, the moho and this upper part of this mantle which is forming above the asthenosphere that is the lithosphere. So, this new plate material generated at this seafloor spreading only, at the mid-oceanic ridge only. The new oceanic lithosphere once created forms a part of the rigid plate. The new lithospheric plate which is generated at the mid-oceanic ridge become this part of this rigid plate and it may, but need not include continental material and this is also very much important because in the last class as we have discussed an oceanic plate may be of entirely oceanic.

However, a continental plate may not be of entirely continental. So, that means, an oceanic plate it may be independent, but the continental plate, it may not be independent. That is why here the new oceanic lithosphere once created forms becomes a part of this rigid plate and may, but need not include the continental material. So, it may be this entirely of oceanic material which is added here which may not be part of this continent. That means, suppose I am talking about this continental system and this is the oceanic system and I am creating a mid-oceanic ridge here.

So, this material which is created here and added this becomes a part of this oceanic system only, but not this continental system. So, that means, the continental material is not created at the mid-oceanic ridge, it is the oceanic material or oceanic lithosphere which is created at the mid-oceanic ridge system. The earth surface area remains constant this is the very much or very important assumption this earth surface area remains constant. So, therefore, the generation of new plate by seafloor spreading must be balanced by the destruction of the plate elsewhere. So, now, if you see here we have mid-oceanic ridge system we are creating this oceanic lithosphere from here and this oceanic lithosphere once it is created it becomes the part of this rigid plate system and the entire plate it is moving.

So, the area which we are increasing here at the assumption said the earth's surface area remains constant. So, this increased area must be compensated by subduction. So, that is why whatever the area is added here that much area has to be consumed here and here in this globe if you can say suppose this is a plate A and this is plate B and this is plate C and these are this boundary between plate A and C and this is between C and B and this is A and B. Now, with time suppose plate A it is moving towards west once it is moving towards west that means, gradually it is covering this much area. So, this is the overlap area it is the convergent boundary and once this area is increasing.

So, that means, here we are creating a divergent plate margin. So, from the divergent plate margin we are increasing this much area and that area is compensated here at this convergent system. So, that means, between plate A and B it is a divergent margin at one end and it is in convergent margin at the other end. However, if you see here between plate B and C and A and C we are creating transform fault here we are creating transform fault here this is dextral and this is sinistral. So, that means, the main theme of showing this figure is once the area we are increasing anyway that same area must has to be destroyed or consumed by other places.

So, that the earth total area will remain constant. The plates are capable of transmitting stress over great horizontal distance without buckling and the other one the relative motion between the plate is taken up only along this plate boundary. For example, if you see here this earthquake distribution and the volcano distribution that defines the plate boundary position. So, now, suppose we are talking about this pacific plate. Now, this is the boundary of this pacific plate.

Now, you see most of this earthquakes they are occurring at the plate boundary and hardly there are certain that is called the intraplate earthquakes or the hotspot related earthquakes they are there otherwise this entire earthquake system they are just surrounding the plate boundaries. So, that means, it says the plates are capable of transmitting stress over great horizontal distance. So, here we are creating at the mid-oceanic ridge we are creating this and we this plate is travelling in this direction now it is the trench. So, without buckling this entire plate is travelling and here this disturbance is there here the disturbance is there. So, that is why the plate is transmitting stress to great horizontal distance without buckling in between and this disturbances they are only restricted at the plate boundaries.

Similarly, here in this diagram you can see this mid-oceanic ridge here we are creating the plate and the plate is moving without any disturbance without any buckling. However, once it is reaching at this subduction zone there is plate interaction and due to this plate interaction there will be folding, there will be faulting, there will be thrusting, metamorphism, everything is there. Here however, the in between the segment of this plate is structurally or tectonically undisturbed that is why this is one of these assumptions which is which says that the plate can transfer stress to great horizontal distance without buckling. Similarly, in Indian plate scenario you can say that this here the Himalayan system and here this mid-oceanic ridge the plate is created Indian plate is created here and it is transferred up to this Himalayas without buckling in between. So, that means, this stress can transfer to horizontal distance to a long horizontal distance without buckling of the plate in between.

For example, here it is a diagrammatic representation suppose we have two plates having length L1 and L2 and thickness of T1 and T2 and these two plates they are moving towards each other. So, that means, we are expecting a collision or a convergent margin here. So, now, you see once two plates are interacting and one plate being the L1 is the heavier one it is going down and forming a convergent plate margin. And once there is a convergent plate margin or there is a collisional plate margin. So, gradually this thickness around this collisional zone it is increasing the rocks are folded the rocks are thrusted.

So, most of this deformation that occurs along this plate boundary and once this system is consumed that means, this area we are reducing at the other end we have to create a rift basin. So, we are creating a rift basin here to compensate this area because here we are consuming the area. So, the area is reducing on the earth's surface. So, to compensate that we are creating a rift basin. So, that we are spreading the system and creating new area here.

So, these are the disturbed zone here either it is rift basin or rift margin or it is a collisional or subduction margin these are the disturbed zone. However, in between this middle part this is the undisturbed zone and that is why it is said this plate can transfer stress from this beginning one end to the other end without buckling in between. So, the basic concept of a plate tectonics is that the lithosphere is divided into small number of nearly rigid plate like curved caps on the sphere which are moving over this asthenosphere. Now, you see here we have this lithosphere I have been thickness this much and now we have a plate here this plate if you see it is looking like a curved cap. So, here it is also one curved cap this is another curved cap.

So, this lithosphere system it is a rigid system which is divided into different curved caps of different dimensions and this curved caps they are separated by this mid-oceanic ridge system. And most of this deformation which results from the motion of the plates such as stretching, folding, thrusting and shearing that takes place along the edge or the boundary of this plate and not in between. So, that is why we can say this stress can be transferred to large horizontal distance without buckling in between. So, only the plate boundaries are disturbed. Deformation away from this plate boundary is insignificant.

So, that we have already discussed. Now continental and the underwater mountain chains occur along this plate boundary. So, this plate boundaries are not very simple. Geometry-wise their difference is there, topography wise difference is there, igneous that means, rock type wise difference is there, metamorphic-wise difference there, mineralization wise difference is there. And topography wise this plate boundary can be understood in terms of this continental and underwater mountain chains.

If you see here we have alpine Himalayan mountain chains this is representing the plate boundary between Indian plate and Eurasian plate. Similarly, we have this Andes mountain this is representing the plate boundary between the pacific plate and the South American plate. Similarly, we have different plate boundaries which are submerged under ocean. So, like this mid-Atlantic ridge, you can see here this is nothing the submerged mountain chains. Similarly, this is a submerged mountain chain this 90 east ridge is submerged mountain chain.

So, that means, either it is a continent or it in the ocean this plate boundaries they represent this mountain chains of large distance and that is why topographically they are distinguished and lithologically, metamorphism wise, mineralogy wise they can be distinguished. Now if this is a plate boundary for example, this Indian and Eurasian plate this is the plate boundary. Now the question arises whether the seismicity or this activity or the deformation all along the boundary remains same or there is a difference. Here comes the seismic gap concept. So, seismic gaps if you see here in the Indian Himalayan scenario.

So, this is representing a plate boundary or this can represent a convergent or a collisional plate boundary. You see there are certain earthquakes they are concentrated here, there are certain earthquakes they are concentrated here and some earthquakes they are concentrated here. That means, in between these area are tectonically undisturbed or not experienced in earthquake more than 300 years and the earthquake of magnitude 8 or more. So, this is called seismic gap. So, seismic gap is nothing it is an area must be within seismically active zone otherwise if I say we are we have peninsular India it is a seismic gap.

So, it is not true because peninsular India is a craton which is seismically stable or tectonically stable and at the plate boundary if you see the Indian plate boundary this is the seismically active zone. So, within that seismically active zone we have some areas identified which are seismically relatively inactive. So, that means, here the strain is not releasing. So, strain active stress accumulation is there. So, that means, these may be the sites of a future great earthquakes we cannot say, but here the seismic gap says the area within the seismically active zone has not experienced 8 or more than 8 magnitude earthquake for more than 300 years this is this can define the seismic gap.

So, now, we have different seismic gaps this is central seismic gap, eastern and this western. So, number of seismic gaps there existing in the Himalayan system. So, this seismic gap it says that this area in between they are seismically relatively inactive at present. So, that means, it says though we have a plate boundary of 100s or 1000s of kilometer, but the entire boundary may not be seismically uniformly active throughout. So, that is why depending upon the rate of convergence, depending upon the rock types, depending upon this fault system, depending upon this upliftment.

So, this area can be identified which are relatively less deformed or less active less interacting with the ongoing plate boundary system. Seismic map of this earth outlined this plate very clearly because nearly all earthquake as well as most of this earth's volcanisms occur along this plate boundaries. For example, if you see here this Indian scenario only. So, if you see these are the earthquakes and volcanoes they are distributed and they are representing this plate boundary. And this plate boundary similarly this can be represented in the global scenario if you see the distribution of earthquake and volcanoes distribution of earthquake and volcanoes here and here.

So, this has nothing this represent this plate boundary. So, now, if you see this East African Rift Valley here this is the plate boundary it is representing. So, this will be part of this African plate and this will be part of the Somali plate. So, that means, this earthquake distribution and the volcanic distribution that define the plate boundary position on the earth’s surface. And these seismic belts are the zone in which differential movement between the nearly rigid plate occurs.

Differential movement occur that means, relative motion with respect to each other that occurs here. Now, if this plates are moving and it is moving from the Precambrian to recent. So, what has actually changed it is the dimension of the plate has changed that means x, y and z has changed. X, Y that is the aerial extension has changed and z is the thickness changed because if you remember our Precambrian when we are talking about the Precambrian tectonics that is the earth's crust or the lithosphere was very thin and this plate motion was very rapid. However with time gradually the mantle it radiated the heat and it is cooled down become this part of this lithospheric system and one segment or this cooled part of the segment of this asthenosphere it welded below the crustal system.

So, this crustal thickness or the lithospheric thickness increased. So, that is called vertical accretion. Accretion means addition vertically we added one part. So, that is called vertical accretion. Similarly at the beginning of this earth when this continents were very small newly formed by magmatic differentiation and this continents which are roaming here and there due to this high rate of motion of this convection current and they amalgam with each other and forming a full-fledged continental system.

So, that is why the X, Y and Z or this dimension of this plate has changed significantly from this Precambrian earth from this beginning of this earth up to now. For example, if you see for here suppose for I am talking about this Indian plate or Australian plate here you can say this Indian plate's configuration there is no difference between these two plates. Similarly with time you see the Indian plate how it is getting separated and here it gets separated and here it is like this and here is like this and here is the Indian plate system. So, that means, similarly if you notice other plates like Australian plate, African plate, South African plate, its dimention change with this geological time and these dimension change it depending upon its interaction with the supercontinents cycle and its interaction with the say mantle system which is convecting below it.

So, it changes its dimension. Although the plates are made up of both oceanic and the continental material usually only the oceanic part of any plate is created or destroyed that we have already discussed though these plates are made up of oceanic lithosphere as well as continental lithosphere. However, the oceanic lithosphere only take part in active subduction and creation. However, the continental lithosphere which was created during this Archean or Hadean time that remains as it is and though it has undergone many phases of deformation, metamorphism, igneous activities, but still it is not subducted it remained on the surface and near to the surface. And this oceanic lithosphere once it is created, but it is may not sustain for longer geological time that is why at present day the live ocean basin it is up to cretaceous or so. However, if you want to see this older ocean basin you have to go for this ophiolite sequences lying here and there on this earth surface.

So, that is why only the oceanic lithosphere is recycled and this continental lithosphere which was formed during this Hadean or Archean or much before that period that is remaining nowadays too. Sea-floor spreading at the mid-oceanic ridge produces only the oceanic lithosphere. So, and we have discussed the only the oceanic lithospheric system is developed at the mid-oceanic ridge not the continental lithosphere. So, it is hard to understand why this continental material usually is not destroyed at the convergent boundaries and this answer is the density contrast. Because if you see it is probable that if the thick relatively low density continental material that is low density means

2.8x10^3 kg / m^3 it is reaches the subduction zone it may descend to certain extent, but below that when it is representing or when it is opposed by the mantle because its mantle density is much much higher than this continental lithospheric density. So, the lighter material it is not able to descend into the heavier material. So, there is a opposite buoyancy system. So, this mantle system it repels back this continental system and it comes out that is why the oceanic lithosphere which is equivalent to this density to this mantle. So, that is created and destroyed, but this continental lithosphere which was created during the early stage of this earth's formation they remain as it is without any subduction.

So, subduction occurs as long as this oceanic lithosphere is attached along the system. For example, if you see here we have a subduction system and this is the oceanic part and this oceanic part is there that is why it is getting subducted. And now if you see compared to these two images this width of the ocean is getting reduced because the oceanic lithosphere is going down like the Tethys ocean which subducted below this Eurasian plate.

So, gradually the ocean's width is or it is reducing and with the breaking of this segment of the oceanic crust this position of this subduction zone it shifts. For example, if you see here once it is subducting here suppose this part is subducted down and become separated from here it breaks. So, now, this part will try to subduct once this part will try to subduct that means, the subduction zone earlier this position was existing now it is shifting in this way. So, that means, the position of this subduction zone gradually changes and if you remember our earlier class when we were talking about the relative motion how this plates are created and destroyed how the plate boundary configuration is there it is changing with time it is changing depending upon the relative motion that was well explained there. And here this says until unless this oceanic system it attached to the system that means, this subduction system is going on.

Otherwise once this oceanic system is totally consumed these two continents they come close to each other finally, they collide and forming a collision zone and this is the mountain building movement are there mountain building activities are there. So, once the oceanic lithosphere is consumed the adjacent continental lithosphere interact with each other and collide forming a collisional zone and part of this continental plate subducts to certain extent. However, it is not able to descend into this asthenosphere which is higher density and that is why it is returned back and this is this assumptions the whole plate tectonic theory is based on.

So, thank you very much. We will meet in the next class For the next discussion.