Plate Tectonics
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Week - 03
Lecture - 11
Types of Plates and Plate Margins

Okay friends, good morning and welcome to this class of plate tectonics. If you remember up to the last class, we have talked about the lithosphere, the crusts, the oceanic crust, the continental crust, the transitional type of crust. So, taking all these in account, so, we have classified the plates and the plate margin. And what is this need of classification is, it is for convenience to understand because Suppose I am talking about this continental crust or the continental plate. So, that means, once I say it is continental plate that means, its nature, its composition, its thickness, its thermal boundary, its gravity, all these things come in my mind. Similarly, once I say it is a oceanic plate, similarly, its nature regarding its thickness to its sedimentary thickness, then its mineralization, its mohos and all these compositional related and structural related things that come in my mind.

That is why these type of plates and plate margins, they are classified for the convenience of understanding. So, now, the question arises, what are the different types of plates and plate margin that we are dealing with throughout this plate tectonics. Before that we must know the plate, it is aerially large body and its thickness is much much less compared to its areal extent that is why we said to be a plate. So, now, if you see types of plate, broadly there are two types of lithospheric plate.

What is that? One is called continental plate, another is called oceanic plate. So, the name continental plate, it says that the maximum part of this plate it is of continental nature. So, that means, this crust is of continental crust and the lithosphere it is the continental crust and this moho and the upper part of this upper mantle it is constituting the continental plate. Similarly, once I say it is a oceanic plate that means, mostly it is composed of a oceanic lithosphere and that means, the oceanic crust itself and this moho and this upper part of this upper mantle.

So, here the continental plate and oceanic plate once we say, so, it is this continental plate which may or may not independent. So, that means, once I say it is a continental plate not necessarily always it is composed of the entirely of continental origin.

Similarly, once we say it is a oceanic plate, the oceanic plate also may or may not be independent, but in most cases the oceanic plate is independent that means, it may not be associated with continental lithosphere. However, once we say it is a continental plate in maximum cases it is not independent part of the oceanic system is associated with it. So, that is why it is mentioned here none of this continental plates are entirely of a continental.

So, that means, if you see here we have different types of plate for example, Indian plate. So, Indian plate the boundary is defined by here and you see we have this Indian continent up to this and this much is totally constitute of ocean. Similarly, we say it is African plate this boundary is lying here and here if you see this part is representing the continental side and this part it is the oceanic side. However, if I talk about this oceanic plate for example, the Pacific plate here you see the Pacific plate this entirely it is composed of ocean. Similarly, this side it is entirely composed of ocean.

So, that means, I can say this continental plate it is not independent always and always or in the maximum cases it is associated with partly oceanic system. However, the oceanic plate is independent so that means, it is composed of the oceanic system only. So, there are many oceanic plates of entirely of oceanic origin and oceanic lithosphere is associated. However, the continental plates always and always there are some part of this ocean is associated with it. So, now different type of plate margins.

So, if you see here this is the tabulated format of different types of plate margins and their characteristics or certain characteristics associated with it. First the type of plate margin there are broadly three different type of plate margin. One is the divergent margin. The divergent that means, the name says it is diverging. Two different plates they are diverging from each other they are moving away from each other that is divergent plate margin.

Then convergent plate margin, the convergent plate margin again the name suggests it is the convergence that means, it is the mixing that is interacting with each other that is called convergent plate margin. Then third type of plate margin that is called transform plate margin. Transform plate margin there is a transform movement. So, neither it is convergent motion nor it is divergent motion. However, it is a transform motion that means, relative to each other they are moving parallely.

So, that is called transform plate margin. So, here this motion if we consider and we compare the motion among these different types of plate margin. The first the divergent plate margin the motion is spreading. If you see here this is the animated figure. So, here this is the divergent plate margin.

So, the two plates suppose plate A and plate B they are forming from this mid-oceanic ridge system and they are diverging away from each other. So, that is called divergent plate. This is the spreading axis. Here the plate spreads or this mid-oceanic ridge it is spreading here. So, this is the spreading motion.

And this second type it is the subduction. Subduction means going down. Here if you see there are two plates again suppose we consider it is plate A and this is plate B. Now, if you see from here one plot of this plate it is subducting below other, this white portion here this is subducting below other. So, that means, this is the subduction motion that means, one plate is subducting down.

For example, India and Eurasian. Nowadays it is representing the collision zone at the northern side and the subduction zone at the eastern side. So, before this collision zone appear. So, Indian plate or the tethys oceanic system or the oceanic plate it was subducting below the Eurasian plate. So, this is the subduction motion.

And third is the lateral sliding. Here if you can say this two plates suppose again plate A and B they are sliding laterally with each other. One is moving in this way another is moving in this way. So, they are laterally sliding with respect to each other that is called the lateral sliding motion or transform motion. Then what is their effect? The effect if we compare here the first or the divergent system it is a constructive effect this is means the oceanic lithosphere is created.

So, here the entire lithospheric column that means starting from this crust, the Moho and part of this mantle or this upper mantle this whole column or this ophiolite sequence you can if you remember we were talking about this ophiolite sequence the whole ophiolite sequence it is creating here. So, this is the constructive system. So, here the plates are being constructed. Then this is this convergent system that is the destructive. So, destruct means one part of this plate is being destroyed here.

So, that is destructive system. So, it is consumed partly this oceanic system or the oceanic segment if you see here this is the oceanic plate which is the oceanic lithosphere is there and that oceanic lithosphere is subducting down it is being consumed there. Then third one that is conservative neither it constructs nor it destroys it conserves the area.

So, here lithosphere is neither created nor destroyed. So, that means, only they are sliding past with each other with respect to each other.

So, this is the conservative motion. Then topography if you compare this topography at the divergent plate margin it is a ridge or it is a rift. If you see here this gradually you are coming and finally, you are moving slightly up and then it is going down. So, this is a positive structure that means, you are moving here on the ocean floor and at the ridge you are coming to a positive structure then you are coming again to the ocean floor. So, this is a ridge or sometimes it is called rise.

So, in East Pacific rise and this mid-Atlantic ridge these are the terminologies they are used depending upon their geometry, depending upon their topographic expression. The it convergent margin we are generating trench that means it is a deep-seated, elongated area where the plates are consumed. So, here one plate suppose it is subducting down this is the abducted plate or the overriding plate. So, here this is the trench. This is the deepest area you can remember that the Mariana trench which is the deepest part in the among the trenches.

So, this is the trench is generated at the convergent margin. However, here at the transform motion there is no major topographic change takes place provided that this boundary between plate A and B it is straight. However, if the boundary between plate A and B are not straight for example, suppose this is type of boundary that means, it is a curved boundary. Suppose this is plate B and this is A and they are moving with respect to each other this one is moving this way this one moving this way. So, now, at this curve here there will be compression.

Similarly, at this curve here there will be compression. So, once there is a compressional force is confining here and here that means, related to the compression there will be topography related to that that will be generated that is transpression related topography. Similarly, here there will be divergent motion and there will be trans-tensional topography in future classes we will talk about positive flower structure, negative flower structure they are associated with this type of motions. Then volcanic activity if you compare it is yes we have volcanic activity. You can see it is clearly that this magma is rising from this mantle level and it is filling this gap which is formed by this divergent motion.

And here if this plate is moving down once it interacts with the asthenospheric system it melts partial melting takes place in the mantle as well as the subducting plate and finally, volcanoes are generated here. So, these volcanoes they represent the volcanic arcs or island arcs depending upon the position, depending upon the plates on which they are emplaced. Here however, there is no volcanic activities associated with it. So, these are the differences or the broad difference between the different types of plate margins. Here in the diagrammatic way it has been explained.

If you see here this is the initial stage of rift generations you can say these two segments they are rifting and there is a is a graben which is formed and with time the graben widens its position and it is occupied by this magmatic material which is derived from this mantle and full-fledge ocean basin is generated here. And there if you see at the present day this analog to this system it is representing at the eastern African system that is the east African rift valley. Here the east African rift valley now you can say how this magmatic plume is generating here and it is affecting the mantle system or the affecting this crustal or the lithospheric system and finally, an ocean basin is generated and with time the ocean basin is widening its position. So, this type of system it is happening from this beginning of the earth up to now. And related to this convergence if you see this Indian convergence is the live example here the convergence is going on the Indian plate it is moving gradually from south to north and it is colliding with the Eurasian plate and finally, it is creating the Himalayas at the collisional zone.

And talking about this transform motion this is the San Andres fault which is a famous fault for transform motion and here due to this transform motion this if you see plates try to slide past with each other this is the transform fault and plates stick to jam together. If you see here this is not an easy process to move this part is locked. So, that is why maximum deformation they are occurring here. Then huge amount of pressure is built up once it is locked up. So, huge amount of pressure is built up and this pressure is being released by violent earthquakes and the violent earthquake is there the pressure is released creating violent earthquakes here.

Then the plates move on few millimeters and no volcanic activities is associated with it. However, if it is curved for example, as we have discussed few minutes back if this is a curved one. So, here you can get this positive flower structure and negative flower structure which are representing the transpression and transtension regime. What is transpression and transtension regime? We will talk in detail when we will talk about transform plate margin. Now, the question arises if the plates are moving and they are interacting either towards each other or away from each other or slide past each other.

Is it the present day process? No. If you see this paleo geographic map or this land and sea distribution from 250 million years, 200 million years then 145, 65 and present day. You will find that this land and sea configuration is different at different geological times. And this is the animated version what is explained here. If you see how this time is reducing from recent and to this maximum it is going down about 250 million years. So, now how this system is behaving, how the plates are moving with respect to each other, how there is divergence, there is convergence, there is amalgamation, there is slide past with each other.

So, this is a continuous process. It is from the longer geological time or you can say from the beginning of this earth, beginning of the continental and oceanic system up to now this process is going on. However, the major difference is that in the Precambrian time or at the beginning this rate of motion was different and here at the present time the rate of motion is different. Even if in the Indian context if you see this India around 55 million years it started colliding with the Eurasian plates and started building the Himalayan mountain. Before that the motion of Indian plate was different. Nowadays it is moving about 5 centimeter per year absolute motion.

However, if you go to 70 million years back or so, this Indian plate movement was 16 centimeter per year or so. So, that means I want to say that the though this system is repeating from the beginning of this earth up to now, however the rate of change or the rate of motion of this plate they are changing drastically. Now, there is a very beautiful term here that is called Wilson cycle. Wilson cycle it says it is a cyclic process that means closing of this ocean basin and opening of this ocean basin. The same ocean basin it is created and the same ocean basin it is closed with geological time with different process.

So, this is a cyclic process and it is called Wilson cycle. So, Wilson cycle says breaking up of lithospheric plate and their coalescence promotes opening of new ocean basins and their closure. This cyclic process is called Wilson cycle. For example, if you see this image here explained. Now we have one continent and this whole continent entirely it is divided with time into two different segments and we are creating a rift basin here.

You can see the horst and the grabens they are the normal faults they are generating. So now, it is going to the second number with time more and more drifting it is creating a ocean basin in between. So, here the ocean basin is full-fledged ocean basin is developed. Now once the ocean basin is developed the basic assumption of the plate tectonics says that the end area of this earth remain constant. However, once we are creating ocean basin here that means we have to consume same area somewhere.

That is why we are starting subducting the system. So, the ocean basin once created here from this mid-oceanic ridge is now it is subducting down below this adjacent plate. So, with time one side is totally consumed and with time next side is consumed. So, these two plates they are moving towards each other and finally, they are colliding and once they are colliding they are creating a collisional mountain system and these two plates they are amalgamated like India and Eurasian plates today. Once upon a time they are separated by tethys ocean in between now the tethys ocean is not existing. So, this Indian continental system and the Eurasian continental system now they are amalgamated together and forming a single landmass.

So, this is cyclic process again there will be breakup again there will be ocean basin development and again there is a closure. So, this is a cyclic process which is going on and this is called the Wilson cycle. And the geological evidences for the repeated occurrence of continental collision and rift in since the Archean has led to the hypothesis that this continents periodically coalesced to large landmasses called supercontinent. So, not only the oceanic system that is created and destroyed. Similarly, the continental system with geological time they have changed their configuration.

For example, if you see this image 1, 2, 3, 4, 5 there are number of continents their coalescence together and forming a supercontinent. So, with time this dispersal occurs and the supercontinent breaks up and finally, different continents they are moving in different direction, there are linear motions, there is rotational motion. So, like that and finally, with time again their coalescence occur and finally, it is forming a supercontinent here. So, this is also a cyclic process. So, this cyclic process of formation of the continent and this breaking of this continent it comes under this umbrella that is supercontinent cycle.

And this occurrence of ocean basin and its closure it comes under the umbrella of Wilson cycle. So, Wilson cycle it is a subset of this supercontinent cycle because supercontinental cycle it is huge, it is huge scale, it is the worldwide scale. However, the Wilson cycle may be of relatively local not the whole local you can say it is a relatively local. For example, Indian and Eurasian plate it is not a supercontinental cycle it comes under Wilson cycle. Madagascar separated from India it is a Wilson cycle, but this Gondwanaland formation, Laurasian formation this is supercontinent cycle there are number of continents they amalgamed together forming a huge landmass that is called a supercontinent.

So, here two types of interaction first is broad upwelling and downwelling they define the mantle convection cell. Why it is happening so? Why this supercontinent is breaking up? Why they are colliding or coalescence occurs? So, below that the mechanism which is working that is the upwelling and downwelling system of this mantle system. Wherever there is upwelling so that means, it is separating the continent. Wherever there is downwelling that means, they are taking these continents together. That is the impingement of deep mantle plumes and the base of this continental lithosphere is one of this region.

So, deep mantle plume how it is generated and how it is generated how and how it moves, how it under plates below this continental lithospheric system and how it changes this heat production and with this change of heat production how this continents try to move that is explained in this animated diagram. If you see we have the mantle convections that means, below this lithosphere we have the asthenosphere and the asthenospheric material they are deforming in terms of plastic deformation. It is not solid it is semi-solid and it is deforming at the plastic deformation and these are the area where upwelling occurs. You see these motions are towards up.

This is upwelling region and this is the downwelling region. If you see this is the downwelling region and the downwelling region they are representing the subduction zones. Similarly, here is a downwelling region this is representing a subduction zone and the upwelling region that is representing the development of the mid-oceanic ridge. You will find MOR mid-oceanic ridge here and you will find a subduction zone here the subduction zone here. So, this is a continuous process in the mantle due to the heat imbalance it occurs and it is moving the lithospheric system which is just above it. Now if you zoom this system here now you see from this mantle this mantle plume is generating and the mantle plume moving up and this is the continental lithospheric system and it is breaking the continent by this development of this mid-oceanic ridge.

First the rift basin developed and with time a full-fledge mid-oceanic ridge is developed. So, two continental mass they are moving away from each other and if you see at the base of this lithosphere and the asthenosphere see this asthenospheric material it is moving and this is the lithospheric material. So, there are shear zones there is a shearing motion that depends upon the rate of motion between this or the change of rate of motion between these two. If it is moving at the same rate as this mantle material moves or at a different rate. So, that defines what type of shear zone will be developed how intense shearing will take place.

So, anyway there is a shear zone that exists along this boundary. During the periods of dispersal, the continent tend to degrade over cold downwelling in the mantle where they act as a insulating blanket. So, now if you see this image here these two continents they are moving towards each other that means these are the region of downwelling these are the regions of downwelling. So, now with time these two continents they are colliding and coalescence forming a single continent. We know the continental landmass or the continental lithosphere it is composed of granitic to granodioritic composition and this granitic granodioritic composition once we are creating a blanket of granitic to granodioratic composition it behaves as a insulator it does not allow the heat to transfer. So, once it behaves like a insulator so, it restrict the heat to radiate.

So, that is why the temperature increases once the temperature increases it creates the partial melting. So, due to partial melting the melt generates and finally, the melt will try to move up. So, that is why here the swelling occurs and finally, due to swelling occurs the rifting occurs here and due to the rift these two continents again separate from each other and they are moving away from each other. So, this is a process by which it is the accumulation of heat below this continental lithosphere and due to this heat generation or the heat restriction. So, it will try to convect the system and due to this convection these rifting takes place and finally, the continents break into different parts.

So, the mantle consequently heats up altering the convection pattern and the supercontinent rifts apart with response to the resulting tension. So, that is why the supercontinent cycle again begins. The continental fragments then move towards the new cold downwelling resulting from the change of this convective design. So, this is a process and this process is a continuous process or you can say it is a cyclic process this comes under supercontinent cycle. So, this supercontinent cycle and this Wilson cycle they substantiate with each other and the supercontinental cycle it is worldwide it happens that is why the Wilson cycle is a subset you can say in the supercontinent cycle.

Now if you see this image here we have supercontinents Pangea around 200 million years, we have Rodinia about 750 million years, we have Nuna around 1400 million years. So, these supercontinents once upon a time they were existing on the earth with amalgamation of many continents and due to this type of heat build-up and due to this change in convection pattern they broke into several continents and they dispersed and may be the new configuration if you see this is the configuration around 200 million years and around 750 million years. Now you see this two configuration it is not possible or it may or may not possible that all this amalgamation which was occurred around this time is remaining at this time. So, there will be new amalgamation, new breakup and new supercontinent form taking different continents together. So, the reversal is caused by trapping and the building of the heat and this buoyancy force in the interior of this convection cell and the plates change their direction around 300 million years.

So, this is the process it takes around 300 million years how the plate change their direction. So, until unless it is an average around 300 million years this plate motion remains unidirectional. Then once this continent breaks up and they are moving and this oceanic system is developed and the oceanic system subducts down. So, this is the mechanism that is the slab pool mechanism and the trench suction mechanism forces they are important as mantle downwelling and upwelling in the breakup of the supercontinent. So, here the slab pool that means, if you see here once this slab is going down it pulls down rest of this segment.

So, this is one of this mechanism of plate motion another is the trench suction. So, this trench it sucks down this material and once this trench sucking down and it is the rest of this lithospheric that is the oceanic lithospheric system it comes down. So, the role of hotspot upwelling and the deep mantle plumes during the continental breakup is uncertain. Because you see this is the hotspot system and the hotspot system we know the hotspot magma is derived from the D double prime layer and it is a high-velocity magma which is coming from the deeper inside from the core-mantle boundary and it once it is coming here without affecting the surrounding or much affecting the surrounding this magma is in placed here as hotspots. So, it acts like a bullet firing so that means, this magma it is coming as a bullet and without disturbing the surrounding it is in placed here.

That is why the hotspots magma's activity or the role in the continental breakup is uncertain. However, this magma which is generated from this mantle and under plating at this continental lithosphere below and it is surrounding and it is breaks this system into different parts and it is moving this continents apart so that this continental breaks up takes place. So, this hotspots magma's role that is why it is ignored or it is less understood in this continental breakup. Now, the thermal buoyancy forces due to this mantle upwelling and the traction of this base of the lithosphere caused by the convecting astrosphere may contribute to this horizontal diverting tension that is sufficient to break the continental lithosphere.

So, as we have discussed here there is a the base there is a traction force. So, that is a shear zone developed because this is a rigid system and this is a non-rigid system. So, there is a difference between this motion. So, that is why there is a traction force or a shear zone that is developed here and that results the horizontal deviatoric tension and that horizontal deviatoric tension is sufficient to break the continents into different part. If you see here this part is zoomed here how the shearing occurring here at this base that means, with the lithosphere and asthenospheric boundary. Here if you see the ponded melt and volatiles then localized shear zones then weak low stress changes.

So, here we have weak stress changes and here we have ponded melt system and this layer it is representing a localized shear zone and that shear zone it is the base of the lithosphere it is creating the horizontal deviatoric tension which is responsible for breaking of this continent into different parts. Now not only this convection system it is occurring at the mantle or at the asthenosphere there each convection system at the outer core also. If you see here we have this convection system at the mantle the lower mantle and the inner core is the solid we know it and the outer core is liquid and due to its liquid in nature it convects due to high temperature. So, these convection cells are of outer core and here if you see the depth increasing and here the temperature increasing and this convection system is here. It is representing the outer core and this is the conduction related heat transfer this is the convection-related heat transfer and here this is convection related heat transfer and this is the conduction-related heat transfer.

So, here we have a convection current here we have a convection current. However, the nature of convection are different. Here it is a slow motion, the convection it is a slow motion, however it is relatively speed. So, that is why this convection though it is occurring at the outer core in the mantle, but its role is purely defined distinctly defined. Here the role is for this plate motion and this breaking of this continent and this subduction and creating this rift basins and the mid-oceanic ridge.

However, the convection at the outer core it generates the earth's magnetic field. Here if you see the convection occurs at the outer core produces the earth's magnetic field. We know this earth is behaving like a bar magnet. So, these are the magnetic lines of force and this magnetic lines or the magnetic properties of this earth it is due to this convection at the outer core. So, the outer core is a metallic fluid consisting of mainly iron and this metallic fluid is in motion with the convection currents that act like a giant dynamo converting the mechanical energy to magnetic energy and so, once there is a magnetism there is electricity. So, that is why this magnetic energy is there for the dynamo that is the electricity is developed and to substantiate that we have magnetic field generated.

So, that is why this convection at the outer core is responsible for this earth magnetic field and this convection at the mantle is responsible for these plate motions. Now there is a question can this mantle convection cause the earth magnetic field development because in mantle we have these ferromagnetic minerals there is convection. So, then why the outer core is only responsible for the earth magnetic field and this is due to this motion that is the velocity of motion and that is the material or the enrichment of iron because if you see if this is this earth and this is the inner core and this outer core this is mostly made up of iron. Though iron is here it is present, but it is relatively less as compared to this outer core contribution. Similarly, here the motion is relatively slow it is very slow it is 5 to 6 centimeter per year.

However, here this motion is very fast that is why it is creating a dynamo and this dynamo is related to electric field generation and the magnetic field generation. So, though here we have this magnetic minerals or the ferromagnetic mineral. However their contribution or their presence is very negligible as compared to this outer core composition. Second thing that its speed this motion is very less and very slow as compared to this motion here at the outer core. So, that is why though this convection or the earth convection at this mantle is there, but it is not able to generate earth's magnetic field. So, this is for today. So, thank you very much. We will meet in the next class.