# Plate Tectonics

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**Week - 06**
**Lecture – 26**
**Destructive Plate Margins-II, The Oceanic Trench**

Okay Friends, so, welcome to this class of Plate tectonics. If you remember our earlier class, we just initiated the Destructive plate Margin and here we are going to discuss each and every element one by one and the first one is the oceanic trench. So, if you see this diagram which is animated. So, here one oceanic lithosphere it is undergoing another lithospheric system and this is the deepest part that is the trench is found and this is the deepest part of the worlds' ocean. And if you remember we are constructing one subduction zone here and another is the overriding plate here we are creating one bulge that is the bulge which is formed by the compression. And here in the subduction system also we have a bulge here and it is due to the compression.

And here is the trench which is the deepest part. Now the trench what is its use? Very innovative use is there if you see this yellow colour one that is the nuclear symbol is given. So, mostly the trench is being used to dispose our nuclear waste because you know this nuclear waste they can be very threat to this environment. That is why there is no safer place where we can dispose the nuclear waste.

So, that is why these are the good position where we can dispose our nuclear waste so that it will directly go inside rather polluting our environment. So, let us talk about its geology what this oceanic trench says about. See oceanic trench they are direct manifestation of the under thrusting oceanic lithosphere and are developed on the ocean water side at the both the island arc as well as the Andean type of subduction. So, the island arcs type subduction that is the ocean under ocean and the Andean type is the ocean under continent. Andean type the name it is derived from the Andes mountain where the Peru-Chile trench is there the Nazca plate is undergoing the South American plate and that is why it is the Andean type.

That means, it is in an ocean and continental type of subduction and this island arc type that is the ocean and ocean type of subduction. So, either of this case at the oceanward side we are getting the trench and this is the longest underward depression like this mid oceanic ridge they are the longest underward mountain range. Similarly, trenches are the longest underward depression where the oceanic lithosphere moves into the trench around a global rate an average 3 square kilometer per area. That means, we are restoring 3 square kilometer per area of earth at the trench. So, that means, as this total area remains constant so that means, this 3 square kilometer per area we are also creating at the mid-oceanic ridge.

Trenches along with the volcanic island or the volcanic and island arcs and the Wadati Benioff zone they are the diagnostic of this convergent plate margin. So, what is this Wadati Benioff zone? We will discuss in the later times, but at this time you should remember the trench is there then the Benioff zone there then volcanic or this island arcs are there. These 3 in combination they are the diagnostic features that says that there is a convergent plate margin or there is a subduction zone. Then most of this fluid trapped within the sediments they are coming back inside to the trench. For example, now you imagine we have a system which is a oceanic system which is subducting and the oceanic system we have sediment that is the layer 1 and once this is going down.

So, this cool and surficial environmental condition it was deposited and when it is moving towards a high temperature environment. So, this water is evaporated and it is coming back. So, many of this water which is coming from these sediments they are it is here it is accumulated here and forming a mud like material. So, this is ejecting in terms of mud volcano. So, you probably heard about this volcano igneous volcano similarly we have mud volcano.

So, this muds are erupted here. So, this mud volcano most of this mud volcanoes they are found here at the trench or near to the trench. So, that is why much of this fluid trapped in the sediments of the subducting slab returned to the surface at the oceanic trench producing mud volcanoes and cold seeps. So, these are the petroleum hydrocarbon that is people are using earlier days. So, this mud volcano and cold seeps they are the indicator of subduction zone and closeness to the oceanic trench and these supports unique biomass that is based on the chemotrophic and microorganisms.

So here you can say this is this mud volcanoes they are supporting this chemotrophics microorganisms they are mostly found at the zone. And globally there are about 50 major oceanic trenches which is covering an oceanic area of about 1.9 million square kilometer. So, that means, these are the trenches and out of these 50 major trenches you can say many of them they are occurring at the Pacific's and around the pacific. Now let us talk about some of these trenches around the world.

The first one is the Peru-chile trench which is the eastern side of this pacific here this is the Peru-chile trench and it is about 4500 kilometer long and reaches a depth about 2 to 4 kilometer. So, that means, from the ocean surface it is around 7 to 8 kilometer and the trenches of the western pacific they are typically deeper than that of the eastern pacific that we have already probably discussed that the western pacific trenches they are deeper than the eastern pacific. And the greatest trench around 11 kilometer depth that is the Mariana trench which is here and this is the other side it is the Peru-chile trench is here. So, if you take this profile from the Google earth map around this Mariana trench here you see and you see this depth. So, it is around 10 point something that is around 11 kilometer.

However, the same is here around this Peru-chile trench around 7 kilometer from the surface. So, that means, the western pacific they are representing deeper trenches than the eastern pacific. And around 50000 kilometer of the oceanic trenches it is present in the worldwide and mostly around the Pacific Ocean and some of them are also in the Indian ocean and few other locations. So, how much depth a oceanic trench should be or it could be that depends upon the age of this oceanic lithosphere. So, if you see here this is the mid-oceanic ridge ridge system in the pacific and from this mid-oceanic ridge this plate is generated and it is moving in this way and it is moving in this way.

So, this distance is very less compared to this much distance. So, that is why a plate which is generating here and subducting here it is of relatively younger than a plate which is generating here and it is subducting here because it is moving a less distance than here. So, that means, up to this edge if we compare this side probably here is the that edge that means, equivalent edge can be reported. However, a plate which is subducting here definitely is older than that. So, that is why in the western pacific the oldest part of this live oceanic lithosphere is being subducted as compared to the eastern pacific.

That is why here the strengths are much deeper as compared to this. So, that depends upon the age of this oceanic lithosphere because the more is the age the more will be the rigid. So, that it can drag this overriding plate to a deeper level as compared to the younger one. So, that is why the more depth it can drag the overriding plate the more deep the ocean strength should be. So, that is why the oceanic lithosphere in the western pacific is much older at the then compared to the eastern pacific.

So, trenches are geomorphically distinct from troughs. Troughs if you take a cross section we would have a that means, steep side and is a flat surface flat base and then it is steed side. So, this is a trough this is trough, but if you see this cross section of a trench it is of V-shaped and it is asymmetrical V-shaped not V-shaped it is asymmetrically V-shaped. So, there is a difference in cross section. So, geomorphologically it is distinct from troughs which have elongated depression in the sea floor and stiff side and flat bottoms while the trenches they are characterized by V-shaped profile mostly it is asymmetrical V-shaped.

And the trenches are generally 50 to 100 kilometer width and in section it is form an asymmetrical V-shaped that we have already discussed with the steepest slope around 8 to 20 degree on the side opposite to the underthrusting oceanic lithosphere. If you see here we have a underthrusting oceanic lithosphere here and we are creating a trench. So, this side it is representing a steeper side and this side is relatively a gentler side. So, this is asymmetrically V-shaped where stiffer part is the opposite to this subducting system and it is 8 to 20 degree or so. Sometimes trenches are partially or totally filled with sediment.

For example, if you see here we have this Makaran subduction zone just below Pakistan. Here this is partially filled this is Makaran subduction zone or you can Makaran troughs. So, now, you see we have a trough and we have partially filled we have a trench for example, we have a trench and we are partially filled it. So, that means, we are creating a section like this. So, this is behaving as a trough, but in terms of Cascadian subduction zone that means, here near about where which will be trench here.

So, in Cascadian subduction zone it is totally filled with sediment. So, the reason being this is there are number of rivers they are devoting here and it is close to continent. So, sedimentary input is high. So, that is why if this trench is totally filled even if you cannot fill yes there is a trench exist or not, but here it is partially filled because due to less sediment. So, that is why this trench and trough that can be distinguished geomorphologically based on its shape and based on the sediment fill a trench may behave like a trough.

So, sediment fill of the trench can vary greatly from virtually nothing to these as in the terms of Tonga and it is almost complete in terms of Alaskan trench like this Cascadian one. And the degree of sediment fill that controls the morphology of the inner slope of the trench. So, if it is more sediment is there that means, more support system is there which is that supporting to this overriding plate to not to subside. So, that is defining either there will be an erosive margin or there is an accretionary margin. If it is filled with sediment then it is the accretionary margin, if it is no fill with sediment then it is an erosive margin.

And this is called sediment starved trenches where the sediment fill is less. For example, we have Peru-Chile trenches, we have Tonga trenches, we have Mariana trenches, they have lack of sediments. So, that is why they are called sediment starved trenches. So, some facts about the trench that the subducting slab it is erodes material from this lower part of the overriding plate and reduces its volume. For example, here now imagine we have a basaltic system which is due to faulting due to fracturing that means, we are creating a surface a rough surface due to fracturing due to faulting and having no sediment cover.

So, that means, we are just subducting this rough surface below an overriding plate. So, now here once this rough surface is interacting with the overriding plate there will be erosion of the overriding plate here. And once there is erosion so, that means, the material is removed from here and it is subducting so, that means, there will be a gap and to accommodate this gap there will be subsidence. So, once there is subsidence that means, we are creating some normal faults and due to this normal faults here. So, this material they are slide it down and it is coming to this trench as sediment wets.

So, that means, this is type of margin that is called erosive margin and which has represented in geological map like a triangle which is open triangle. However, contrast to that if we have sufficient sediment filled basaltic system that means, surface which is filled with sediment. Now the sediment is subducting down and it is providing a support to that. So, it is accumulated and here it is creating this accretionary prism and this accretionary prism it is supporting or not to slide this material. So, finally, we are creating the accretionary margin is there.

So, we have erosive margin if sediment is not there, if we have accretionary margin if sediment are sufficient amount of sediment is there. So, the age of the slab experiences subsidence and stiffening with normal faulting. The slope is underlined by relatively strong igneous and metamorphic rocks which maintains the high angle of repose. No thrust rises at this inner slope of the erosive margin are found. However, we have many thrusts here at the accretionary margin because we are compressing in both ways.

So, the sediment which was there it is compressed and finally, thrust slices are developed and these thrust slices there will be a different type of thrust slices different angle and they are originating from different level that is why different type of metamorphic rock assemblages are there. So, over half of the convergent margin they are representing erosive margin. So, here this erosive margin characteristics we have already discussed. Whereas the southern Peru-Chile, Cascadian and Aleutians trenches are associated with moderately or heavily sedimentation trenches. So, like here once we have heavily sediment, the sediment is accumulated here and it is forming an accretionary margin here.

And the inner slope is underlined by imprecated thrust sheets that we have already discussed. The sedimentary wedge is here we are compressing from both side and finally, due to compression we are creating some folds and with folds we have some thrusts like that. So, that is why this imprecated thrust sheets or thrust slices are there in the accretionary wedge. And the inner slope topography is roughened by this localized mass wasting. So, once there is a faulting there will be mass wasting and that is why due to this mass wasting this topography is changed.

Frequent mega thrust earthquakes that is modify this inner slope of the strengths by triggering massive landslides. So, here if you remember our earlier class we are talking about this earthquakes which are the deepest earthquake or severe earthquakes that are felt at the subduction zone as compared to other two types of flat boundaries. And these massive earthquake that modify the geomorphology, modify this rock arrangement pattern because there are frequent landslides and due to landslides there will be heavy erosion. And subduction of seamounts and aseismic ridges into the trench may increase the aseismic creep and reduce the severity of earthquake. For example, suppose this is one overriding plate and this is the subducting system.

Suppose there is a seamount, there is a volcano or there is an aseismic ridge, ridge is there for example, ridge is shown in the cross section. Now we are putting it inside. So, what is happening here this due to this ridge or due to this volcano, so it is creating a gap. So, that means, once there is a gap is there, so, aseismic creeping the creep that means, in geomorphology probably you know this is the smallest or you can say the slowest method of mass wasting. So, once this is a sloping surface and this is free, so that means, relatively free, relatively less pressure is there overburden pressure is there due to the support of this.

So, that means, there is a slow creeping system here. So, that means, aseismic creep is noticed where recorded and where there is a subduction of this seamount or the aseismic ridge. However, if you are putting sediment here, no ridges we are putting sediment. So sediments we are forcefully we are including it we are including this force sediment, so that the sediment will intrude into the fractures and this fractures will open up. So, once the fractures will open up the depth to which the deformation can follow that will be increased.

For example, in contrast subduction of large amount of sediments may allow ruptures along the subduction decollement to propagate for greater distance produce large magnitude earthquakes. So, that is why these large magnitude earthquakes they are mostly found where there will be sediment subduction. Then the trench can roll back. So, it is not a fixed position for it. So, if you see here, these three consecutive figure, this is the position of earlier trench and gradually the trench is shifting in towards its east and finally, this trench is again shifting for further east.

So, why this trench is rolling back? This is called trench roll back. So, though trenches that remain potentially stable over time, some of them are moved back into the subducting plate and there are number of reasons how this trench can roll back. For example, suppose this is the new plate which is subducting.

So, this part is not here. So, this is the trench. Now once this part is moving further down, gradually there will be metamorphic changes, there will be dehydration. So, this becomes heavy. So, finally, it bends down. So, once it is bending down, so that means, there will be a change here.

So, the position is shifting in this way. Suppose this part is break, there is a breakage in this part. So, that means, this part is totally moved down. This is totally detached. So, once it is detached, so that means, here this will move this way. So, that means, the position of trench will again shift in this way.

Suppose melting takes place here and we are creating this way by backarc basin. So, once we have a backarc basin that means, we are creating another mid-oceanic ridge system. So, this part will move this way, this part will move this way. So, as this part is moving this way, this pushes this plate in this way, so that this trench will move in this way.

So, that means, here is a trench rollback. Similarly, once this is moving down and this was the subduction system or the convection system is there and this convection current it is bombarding here. So, that means, due to this pressure of this convection cell, this will bend in this way. So, once it is bending in this way, it is coming back. So, this position of this trench will change. So, there are number of ways how this trench can roll back and it is changing its position.

So, this is called trench rollback or it is a hinge retreat. So, this is the hinge rollback, how it is retreating, it is coming back, it is called hinge retreat. So, forces perpendicular to the slab are responsible for stiffening of the slab and ultimately the movement of the hinge and the trench at the surface that we have already discussed how this hinge is retreating and how the trench is retreating and changing its position. And to explain it further, here as we are discussing that if it is going down and melting, we are creating a backarc basin here. This is the volcanic arc system and we have a backarc basin here and due to backarc basin this block is moving this way, this in the opposite direction it is moving, so that progressively it is bending the system.

So, once it is progressively bending the system that is hinge retreat occurring and the trench rollback is occurring. So, the reason for trench retreat is the negative buoyancy of this slab with respect to this mantle because it is gradually it is moving down because it is become heavy. Once it is moving down there is certain metamorphic change, there will be dehydration, there will be increase in density, so that it bends downward. So, this is the negative buoyancy, it is had it been positive buoyancy it will just move up, but it is negative buoyancy that is why it is moving down. Then the extension of the overriding plate and forming a backarc basin.

So, we are forming the backarc basin here. So, these are the reasons by which the trench retreat or the hinge retreat takes place. And the same thing it is shown here, it is the early phase of subduction. So, now see this is the early phase, this is the trench and gradually when this is going down further down and this due to this bombardment of this convection cycle, so it is moving back. Similarly, further it is moving back because gradually once it is moving down, it is more dehydration takes place, more density increases, so that this becomes heavy. So, due to its own weight and due to this bombardment of this convection cycle, so this part it is retreating back.

So, that is why earlier the trench position was here, later it becomes here and later it becomes here. So, this trench position is gradually changing backward, it is retreating the system. And same thing it is discussed here, it is also diagrammatic way. So, now if you see this subducting plates worldwide, there are number of subducting plates and the subduction angle is different.

So, starting from 10 degree to 90 degree or so. So depending upon this angle of subduction, this trench position also defined, trench geometry is also defined. So, several forces they are involved in the process of slab rollback, two forces acting against each other at the interface of these two subducting plate exert forces against each other. So, that means one is for example, one is moving this way and another is moving this way, so this is the trench. Now if it is moving this way, however this is close to this continent, it is not able to move further, so there is a pile up. So that means there is loading, we are thickening the system, there is loading.

Once more and more loading we are putting here, this system is bending down. Earlier this is the low angle, so now you see this is the high angle. Similarly, more and more loading further, so this part is detached from the system and then it becomes like this. So, this way this trench changes its position, changes its angle of subduction with time. So, there are evidences from seismic tomography that it provides this slab rollback.

So, if you see this seismic tomography and how this slab is rolling back at a different position that is shown here. High temperature anomalies within this mantle suggesting subducted material is present in the mantle. So, because this mantle is totally hot and we are putting a cold plate, relatively cold plate here, so that means a cold slab within the hot mantle. So that if we are measuring this temperature anomalies, this subducted slab will remain as a cool one as compared to this mantle temperature from the surrounding. So that is high temperature anomalies that indicating how this position of this slab with time and that is indicating and that how this subduction angle is varying and how this trench position is varying.

And another is the ophiolite which is providing evidences for the same. So, ophiolite suggesting high pressure and temperature rocks are rapidly brought to the surface through this process of slab rollback. For example, if this slab is rolling back and this is moving up, so this segment this ophiolite which is coming from the deeper level here, from the deeper level it is coming to the surface, so that it is showing this how this slab is rolling back. Because from the different level in the slab rolling back, it will create different slices of ophiolite and that is why different slices indicating different levels, so the different degree of metamorphism. So that means different slices coming from different depth, it is indicating that the slab is rolling back. So, the trench sediment which is called the melange, so it is neither any grain size, specific grain size is there, it is starting from clay particles to larger boulders.

No particular origin is there, it is from igneous origin, from metamorphic origin, from sedimentary origin, no preferred arrangement, totally chaotic there is no special arrangement of grain size, no special arrangement of rock types, no bedding, nothing is there. So, this totally brecciaed system if you see here that is called the melange. So, melange is nothing it is called mixture. So, melange is a large scale breccia, a mappable body of rock characterized by lake of continuous bedding and this inclusion of fragments of rocks in all sites, contained in a fine grained deform matrix.

The melange typically consists of jumble of large rocks of varied lithology. So, it is from this igneous system, it is from this metamorphic system, it is from the sedimentary system, it is from this thrusted metamorphose, thrusted accretionary prism. So, all those rocks they are assembled here and it is forming the melange and this melange, this rock bodies or this rock boulders of different size, they are embedded with the fine grained matrix clay sized matrix and if you remember the clay sized matrix the clay minerals which is coming from this mud volcanoes and this cold seeps. So, all together they are forming one sedimentary package that is called melange. And apart from that sediments are subjected at the bottom of the trenches, much of their fluid content is expelled and moved back in the subduction requirement to emerge on this inner slope at mud volcanoes and cold seeps already we have discussed. And apart from this melange and this mud volcanoes and cold seep there is very important mineral that is found or important entity it is found here that is called methane clathrate and gas hydrates.

So, this gas hydrates they are found at the trench. So, the Mariana trench already we have discussed about. So, this is around this equator and here this is the Mariana trench and this amount of it is a comparison here. As its position is at this equator or near to the equator though it the deepest trench, but still its position is not close to the center of the earth because you see the Mariana trench it is position is near to this equator. However if you see the Arctic Ocean here the trenches which are at the Arctic Ocean already this is equatorial radius and the polar radius there is a difference around 25 kilometer or 16 mile.

So, due to this difference in this earth's radius equatorial and polar radius. So, though it is the deepest trench, but still it is not close to this center of this earth. However here this is the trench which is found at the Arctic Ocean it is close to this earth and this is the marina's position is here and this Arctic Ocean trench the position is here. So, though it is the deepest part, but still it is not close to the center of the earth. However here any trench is here which is close to the center of this earth.

So, this is all about your trench. So, thank you very much. We will meet in the next class.