Plate Tectonics

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Week - 10
Lecture – 48
Stability of Triple Junction

Friends, welcome to this class of plate Tectonics. And today we are going to discuss about the stability of a triple junction. So, now the question arises what is a triple junction? So far we have discussed three types of plate boundaries convergent, divergent and transform. And a triple junction is a junction where three tectonic plates meet. And this meeting point may be stable or may be unstable. If it is unstable for certain reason, then it will change its orientation and the configuration of this plate arrangement that will change with time and finally, it will convert to a stable triple junction.

So, in today's class, we will talk about the different stability criteria and how to assess a given triple junction is stable or unstable. And if it is unstable, if you are changing certain parameters, how that can be stable. So now, if you see this distribution of plates in the worldwide, there are around 50 plates, 50 plates I am talking about the major plates and about hundreds of triple junction. So, here you see the ridge and this ridge and this ridge, three ridges they are meeting at a point.

So, that means, here one tectonic plate, another tectonic plate and the third tectonic plate they are meeting together. Similarly, here this is again a triple junction. So, that means, all these yellow dots they are the triple junctions. But if you see this nature of the triple junction, for example, here this triple junction that is it is around this trench, then ridge, then it is again a trench. So, trench, trench and ridge, here it is ridge, ridge and ridge and here it is ridge and trench.

So, that means, you see the triple junctions are of different configuration. They are placed at one point and where the three tectonic plates they are meeting. So, either a triple junction it will be named that depends upon the types of boundary it is sharing. For example, ridge stands it is R stands for ridge and T stands for trench and F stands for transform fault. In future classes or in this future slides, when we will talking about this RTF, you should know this R stands for ridge and T stands for trench and F stands for transform fault.

Now you see triple junctions can be described according to the type of plate margin that we have already discussed. For example, here it is a given triple junction one here is a triple junction that is RRR. So, three plates they are meeting through their ridges at this point. Similarly, here one ridge is here from this Red Sea, another ridge is from this Gulf of Aden and here it is a fault that is a transform fault. So, this triple junction it is by RRF.

Of the many possible types of triple junctions only few are stable through time. For example, if you see here we have a triple junction here this is one ridge and another transform fault. With time it is changing to ridge, fault and fault. Similarly, this is ridge, fault and fault. So, now here it was ridge, ridge, fault that means RRF.

For example, here it was RRF. Now with time it is converting to FFR. Similarly, this is FFR. So, one triple junction it is converting to two triple junctions. So, that means with geological time number of triple junctions that have been changed. So, that means with geological time number of triple junctions that have been changed and in geological future also the present day configuration may not be there, there will be change in the triple junction.

So, now the question arises why it is changing? It is changing due to stabilize to balance the relative velocity. The balance the orientation of this plate boundary. If you remember our earlier class when we were talking about Euler's pole. So, this relative velocity is changing from pole to equator. I am talking about the Euler's pole and Euler's equator.

Similarly, the orientation of this plate boundary changes with time. So, if the change of this orientation with the change of relative velocity, the stability of triple junction changes. So, one triple junction may be unstable. So, here the RRF junction for example, we have already discussed it is RRF it is changing to FFR. And if the four or more plates they are meeting at a point, this point is totally unstable and with consequence it will be divided into two or more triple junctions.

So, an unstable triple junction exists only momentarily. That means for a few times, few geological times it will exist and then it will convert to a stable triple junction. Now how can you say which one is stable? The stable that means the relative motion of the plates, the azimuth that is the orientation of the boundary and the type of a plate boundaries of the whole system do not change with time. That means if you see here two configurations are given. At this first case, this is a transform fault, this is a trench.

So, here it is FFT triple junction. This is F, this is F and this is T, FFT triple junction. Now if this triple junction is here, either it is moving downward or it is moving upward. In any case, this FFT will remain there. Either it is coming here that means this trench it is shifting to this position.

So, here that means this is the triple junction, here it will be F, F and T. So, that means the orientation of this plate boundary it is remaining same. The position only changing that means the geographic position is changing. Similarly here if this is the triple junction with time this triple junction may move in this direction or it move this direction. If it is moving this direction, so that means the ridge is moving here and similarly this trench is moving up to here.

So, that means you see here the same thing that means F, then T and R. F, T and R and now it is also F, T and R. Similarly if it is coming down here that means this transform fault will shift up to this position and the ridge will shift from here to here, but here again F, T, R configuration will be there. So, that means though the geographic position is changing, but the orientation of this plate boundary it is remaining same, the azimuth remaining same. So, that means the azimuth and the orientation of this plate boundary that is the type of plate boundary and its relative motion of this plate remains same, so that it can be set at stable triple junction. And in this case here suppose this is plate A, B and C and this orientation of plate C and A it is northeast- southwest and this boundary is northsouth and this boundary is eastwest and with time it is converting to this.

So that means here this plate boundary between A and C it is not remaining only north east, here north south component is added and all other things remain constant. So that means this unstable triple junction with time converting to a stable triple junction, why? Because this orientation it is not fitting to this relative velocity among these three plates. So, that is why this position is changing. So that is why the orientation of this plate boundary is changing with time. So, that means new triple junction is stable and this older one is unstable.

So, now as a observer if you are earlier your position was here that means you are standing here with time that means you are sharing the boundary between plate A and B. Now your position at the same position here that means you are sharing the boundary between A and C. So, this the properties of the ridges, trenches and transform fault involved that means a triple junction may be described and their stability can be assessed without use of the geological details. Nothing related to its geological whether it is a which rock and which type of boundary it is sharing it is just the relative velocity and the orientation and the azimuth. These things that is defining to assess the stability and unstability of the triple junction.

Now to solve this triple junction problem we have three assumptions. The first assumption is related to a ridge. What is that? The structures that produce lithosphere symmetrically and perpendicular to the relative velocity vector then either side. So, now you see this is the relative velocity vector and this is the structure which is perpendicular this raising here. So, perpendicular to the relative velocity vector here and it is from both sides it is creating plate for both sides.

And for trench the consumed lithosphere from one side only so that means we believe this plate is getting consumed it is one side only and the relative velocity vector can be oblique to this plate boundary not necessary this subduction should be perpendicular to this trench it may be like this. So, here it may be possible that this subduction may be oblique subduction. And in third in terms of this transform fault it is the active fault parallel to the slip vector because here slip is here. So, this orientation is parallel to the slip vector. So, now stability criteria how to distinguish or whether this three that means the three plates the junction between three plates or the triple junction is stable or not stable.

So, the basic requirement is that the relative velocity of the three plates should be 0. So, that means these plates are not moving with respect to each other. So, this point is not moving actually the plates are moving the points are not moving. So, here we have a north and east orientation that means it is a graph we have to plot a diagram. So, in that diagram we have to plot this velocity vectors depending upon this velocity relative velocity amount.

For example, it is the relative velocity between A and B it is more. So, here and this velocity should be a vector quantity. So, that is why depending upon its orientation which direction the velocity is. So, this velocity vector is like this. So, and here this total relative velocity between these three plates should be 0.

So, that we can say this plate is or the triple junction is stable. And to examine the stability of any particular triple junction it is easiest to draw the azimuth of the plate boundaries onto the relative velocity triangle. That means first we have to create the relative velocity triangle on this northeast quadrant because any geological work it is respect to geographic north. Any dip strike value we are talking about it is respect to north that is geographic north. So, that means on this north if this is north this is east.

So, in this quadrant we have to draw the relative velocity triangle and on this relative velocity triangle we have to superimpose the azimuth of this plate boundaries. Now if this plate boundaries they are meeting at one point on this relative velocity triangle then we say this given triple junction it is stable. So, now how to do it? Let us talk about. So, here for ridge the line constructed must be perpendicular bisector to the relative motion vector because we know this is the ridge and this is the orientation of this plate boundary and this is the vector. So, that means it is perpendicular bisector because both direction it is moving same.

Suppose for example, it is 2 centimeter it is 2 centimeter relative velocity to be 4 centimeter if you remember our earlier class when we are talking about the relative velocity problem. So, that means that is why the orientation of this plate boundary it is bisecting the relative velocity triangle line and that is why this direction and this direction they are experiencing same relative velocity. Is not it? So, that means now I am talking about a north and east that means segment or quadrant. So, here this is the relative velocity. So, here for example, it is 4 centimeter and this orientation of this plate boundary.

So, suppose this is A and this is B here A and B and this orientation of this plate boundary here on this that should be perpendicular bisectors. That means this AB which is the orientation of this plate boundary between A and B it is now this. So, on solving this triple junction problem we have to draw this relative velocity triangle depending upon the relative velocity and on this relative velocity triangle we have to draw this orientation of this plate boundaries and this orientation of this plate boundary has an assumption that we have already discussed. If it is a ridge it should be perpendicular bisectors to this relative velocity triangle and for transform fault the line must be parallel to relative motion vector as all this motions is parallel to this boundary direction. So, that the line AB must lie along the AB transform fault separating the plates A and B.

For example here suppose we are talking about these two plates that is A and B and A and B this one is B not this. So, A and B two plates. So, this relative velocity for example, this is this direction around 6 centimeter for example. So, that means in this diagram this relative velocity will be the relative velocity triangle this should be like this because the orientation is like this and here this AB will be also parallel to that AB is parallel to that because you see this AB that means this orientation of this plate boundary it is parallel to the relative velocity line is not it. Similarly in the trench along the strike of this trench, but remaining on the overriding plate.

So, we have two plates A and B here B is the overriding plate you see the symbols B is the overriding plate and here the relative velocity line AB it is here because the relative velocity triangle is in the triangle this orientation is like this because this plate A is moving here and B is moving here and this is the trench that means orientation of this plate boundary. So, the orientation of the plate boundary is AB it will be parallel to this trench, but it will lie on the overriding plate because if it will be in the under thrusting plate it will destroy. So, it is assumption is that it should be parallel to that, but it remain on the overriding plate. So, these lines AB, BC and CA which are parallel to this plate boundary join the points in the velocity space which all leaves the geometry AB, BC and CA unchanged. So, that means the relative velocity between these three plate is 0 and these lines are same as those that join the velocity space at which the observer could move and give the velocity still remain on this plate boundary.

And when these are drawn onto the diagram containing the velocity triangle these line must be able to meet at a single point for the triple junction to exist stably. So, that means if I am creating one north east quadrant and I am preparing a relative velocity triangle ABC and AB for example, it is one ridge. So, this AB that means orientation it will be like this because it is perpendicular bisectors this is the orientation of this plate boundary. So, that the velocity is from both side and for example, BC is a transform fault. So, this BC will be that means the orientation of this plate boundary that will be parallel to that.

So, that means here I am talking about the BC and for AC if it is trench and the trench suppose A is the obducting plate and this relative velocity in here. So, A is the obducting plate and it should be that means it should be perpendicular to that. So, that means here this should be the AC because this is the orientation of this plate boundary and this is the relative velocity and A is the abducting plate from the A. I am drawing this plate boundary orientation. So, now you see one plate boundary orientation is moving like this another plate boundary is moving like this and the third is moving like this. So, now see in the velocity triangle none of them are meeting at a point for example, this AC and AB they are meeting here.

Similarly, AB and BC they are meeting here. So, that means if this is the amount of that is the relative velocity given with this orientation and that means I am creating a relative velocity triangle of this orientation with this much velocity and this given triple junction is not stable because these three points are not meeting at a point. So, here the same thing is discussed here if AB, BC, CA that means in the given example here the AB and BC they are coinciding with each other and the AC is here. So that means now you see in a given velocity triangle they are meeting at a point. So, that means this is a stable point. For example, shown in the triple junction here ridge, trench and transform fault here this is the ridge, this is the trench and this is the transform fault and in order to be stable this triple junction must be capable of migrating up or down and the three boundaries between this pair of this plate and it is easier to visualize the conditions for stability of a triple junction if each boundary is first considered individually.

For example, suppose I am talking about a trench. So, now A and B are two different plates in which B is the overriding plate. So that means if the relative velocity triangle the relative velocity will be in this way or in this way, is not it? However, the plate boundary orientation will be like this and it will be the plate boundary orientation it will protect from the B because B is the overriding plate. For example, here this is the relative velocity triangle that is one side of this triangle I am going to construct a relative velocity triangle from this given data. So, this is the relative velocity triangle, this is north and this is east quadrant.

So I am just putting this relative velocity amount which is AB and this orientation of this plate boundary AB which is passing from B because B is the overriding plate when this orientation of this plate boundary is like this. Now in the second case if the line BC it is representing the velocity vector between these two plates and this BC is B and C is a transform point. So that means the relative velocity it will be parallel to this plate boundary. Now see this is parallel to the plate boundary BC I have given. Then the plate boundary orientation is also parallel to that.

So, this plate boundary orientation I am superimposing on it. So, this is BC and this is the relative velocity amount. The second part of the triangle is complete. First part of the triangle it was like this. So, it was like this here, like this earlier if you remember this one.

So, B and this is A. So, now this second part of the velocity triangle that means I have completed. Now coming to the third part, so here AC that means A and C it is one ridge. So, one ridge that means your relative velocity vector will be like this or will be like this. So now you see the relative velocity triangle is like this and this orientation of this plate boundary is like this. So, this is the perpendicular bisectrix of this relative velocity triangle line.

So now before that we have constructed like this the triangle and third is I'm constructing like this and this is the orientation of this plate boundary. So, if I am combining these three, so I am getting this, so I am getting a relative velocity triangle of these combining all the three and on which the AB and BC they are coinciding together and AC is here. So now you see this AB, BC and AC they are meeting at a point. So that means I am putting the orientation of these plate boundaries on the relative velocity triangle. So, they are meeting at a single point that means it says this relative velocity or the three that the given triple junction it is a stable triple junction because the relative velocity is maintained here within that triangle.

So the stability of the triple junction can be determined from the relative position of the velocity line representing on the boundary. If they intersect at one point it implies that the stable triple junction exist because that point has the property to being able to travel up and down all the three plate margins. So that means here this point may move up or may be down or this way or that way. So that means this point if it is moving up and down but is remaining within the triangle, so that its relative velocity is maintained, so that it is a stable triple junction. Suppose for example here it is a given orientation that means we have three plates A, B, C and they are sharing the plate boundary which are convergent boundaries and that means first we have to create this relative velocity triangle.

So relative velocity triangle is here and on this relative velocity triangle the super imposition of this plate boundary orientation is there. Now what is happening here? Reason happening here is that this two relative velocity on this relative velocity triangle these two plate boundaries they are meeting. However the third is far far away from the system. So now the question arises if this can move here, so that will be a stable triple junction.

So that means we have to drag this line up to here. So dragging this line up to here that means I am reducing this much from here and once I am reducing this much from here I am also changing the orientation here because this will move here, this one is move that means this plate boundary this relative velocity and direction and amount I am changing. Similar amount is changing and direction is changing. So that means if the amount and direction is changing so that means what changes I am getting in this plate boundary condition that means this orientation of this B and C if I am making this boundary this so that means I am solving this problem. So that means this line if I have to drag up to here so this much amount I have to reduce from this relative velocity between B and C. So B and C the relative velocity if I am changing and the orientation is also changing so that means this line will pass at the same point so this triple junction will be stable.

So that means at a given triple junction if it is unstable with changing certain parameters that can be max stable. So here stable configuration of the triple junction and velocity space representation is here and further condition must also be met for the triple junction to exist stable is that the plate must move in a way that leaves their individual geometries unchanged. Alternatively, the triple junction must move in such a way that it remains on all three of these plate boundaries involved. So these are the conditions that is that means through which the given triple junction can be made stable. So only six type of triple junctions are present during the current phase of the plate tectonics and they are it is given here.

Out of this the RRR it is the most stable one. So it is the junction between east Pacific rise and the Galapagos rift zone. Then TTT this is the central Japan. TTF it is peru-chile trench west chile. FFR possibly at the junction of Owen fracture zone and carlsberg ridge and FFT junction of San Andreas Fault and this Mendocino fracture zone and RTF mouth of the Gulf of California. So this RRR is the most stable one and here some of this configuration is given this plate boundary orientation or the triple junction and on this velocity relative velocity triangle this plate boundary orientations are given and it is that means how whether it is stable or not stable that has been discussed here.

You see this is all orientation stable that means always it is stable and if it is FFF three transform faults are meeting it is always unstable. So these two that means this TTT that is stable at this condition or if certain condition changes that will be stable that has been discussed here. So this orientation is given and this relative velocity is given how this relative velocity triangle is constructed we have discussed that means taking this relative velocity between the two plate. This relative velocity triangle first it will be constructed and on that this plate boundary will be superimposed based on this assumption that this ridge it will be perpendicular bisectors this ridge it will be perpendicular bisectors and this transform fault it will be parallel and in the trench it should be on the overriding plate. So on this principle if you are putting this plate boundary orientation on this that is the relative velocity triangle then if they are meeting at a point then this given triple junction is stable and some other examples that is quoted here. So thank you very much we will meet in the next class.