Plate Tectonics

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

Week - 05
Lecture – 22
Conservative Plate Margin-II, Continental Transform Faults

Ok friends, welcome to this class of plate tectonics. And if you remember our earlier class, we are talking about the oceanic transform faults. And we concluded that this transform fault, the terminology only confined to this active segments, which is separating between the two ridge segments or a ridge segment in a subduction zone or two subduction zones. So, accordingly there are six types of transform fault and with time, the length may increase, may decrease or may remain constant and depending upon the rate of deformation and spreading so, here we will talk about continental transform fault which is altogether different from the oceanic transform fault. So, the most decorated continental transform fault in the world is the San Andres fault it is the western part of the America. So, this is the continental transform fault, exhibit a structural complexity that reflects differences in the thickness, composition, temperature, pressure profiles of this continental lithosphere.

Here, this continental plate, it is may A and B, they are sliding past one another and mind it, this junction, it is a straight line. So, if it is so, then there will be hardly any generation of a plate here or plate material here. However, if we introduce some complexity in its geometry, for example, suppose I am making it curved or it is unrelated, so, this structure will not be as simple as we discussed here, but this complexity we will introduce in the next class how the complexity will change the geometry and it will create different types of sedimentary basins or there is a positive or negative flower structure that is called we will talk in the next class. So, today we will talk about these general characteristics of this continental transform fault.

So, if you see this photograph, that is San Andres fault here, this is the most studied continental transform fault so far and it is exposed and becomes a tourist place. And this is the San Andres fault trace which is separating these two plates from each other. And this is the basin and range province, this side, this is America mostly it is characterized by horst and graben. This is the extensional tectonic regime and here it is the transform fault which is separating this American plate and this is the Pacific plate. So, this transform fault characteristics, how narrow it would be and whether it will create the basin in between and what should be the basin characteristics that depends upon the types of continent through which the transform fault created and it is passing through.

For example, suppose we have a continental lithosphere which is strong, rigid and old, for example, shield areas. So, here if we are creating the transform fault, it will be narrow in nature and here it is narrow zone of deformation so that means there is width will be less and there will be number of pull-apart basins that will be developed along this transform fault. However, in contrast to that, suppose we have a continental lithosphere which is hot and weak like this basin and range province or the southern part of America where the transform fault with a wide deformation zone will be developed. So, if you see this San-Andreas fault and this deformation zone, it is extending up to this. So that means the narrow transform faults or the narrow zone of deformation it will be developed in the transform fault, developed in the cold and rigid regions of this earth and it is a wide zone of deformation it will created in the hot and weak lithosphere on this earth's crust.

Now this Dead Sea transform fault is a plate boundary which is separating the African plate from this Arabian plate. So, this is the Arabian plate and this is African plate. So, these two plates are moving with respect to each other and here we have the Red Sea, the East African Rift Valley in this side and this Red Sea we know this is a divergent plate margin we are creating and due to this divergent motion these both plates they are moving with respect to each other. However, the Arabian plate is moving at a faster rate as compared to this African plate. So, that's why it is creating a left-lateral slip, this is the Sinistral transform fault it is generating here and due to this Sinistral transform fault generation and as it is being created on the shield area, the African shield and it is very rigid and old.

So, we are creating the narrow zones of deformation there. It is a zone of left lateral displacement that is Sinistral motion. Both plates are moving in a general north-northeast direction but the Arabian plate is moving faster. The extensional component of the southern part of this transform fault formed a series of pull-apart basins that is you can say here that is the Gulf of Aqaba and this Dead Sea, the Sea of Galilee and the Hula Basins. So, these are the different basins they are developing at different parts and these are nothing the pull-apart basins.

So, what is the pull-apart basins that we will talk in the next class in detail. Now talking about the San Andres fault, it is a continental transform fault around 1200 kilometer length and it separates the Pacific plate from the North-American plate and it is right-lateral strike-slip fault. Right lateral that means it is a dextral fault which is there. The continental lithosphere is not generated or destroyed in the same manner as the oceanic lithosphere. So, if you remember our oceanic transform fault, there are some leaky transform fault, there are some pure transform fault and here the oceanic lithosphere was generated around it around the mid-oceanic ridge.

However, here this lithospheric part or this continental lithospheric part it is not created here because continental lithospheric development is altogether different process than the oceanic lithospheric system. So, it is this difference that marks the continental transform fault substantially different in behavior from their oceanic counterpart. And if you see these figures of different type of continental transform fault here, here you see we have a marked offset by the transform fault that means this transform fault is generating from this point and with time the length of the transform fault is increasing and with time further increment is there. But these remarkable changes from phase 1 to phase 3 you can see finally on the surface shell on this map section your it is looking as a broom type and this is the initial part and finally, this fault is growing in this way and gradually if you see the width of the deformation zone it is increasing. And finally, this fault is divided into a zone earlier it was started with a line from a point and now it is divided into a zone.

So, this is off-fault tip splay networks. So, this tip is divided into different displays and the direction of long-term fault propagation that means it is saying the direction is representing the damage zone the width of damage zone increases towards the growth direction. And if you see this zoomed version of this we have a inner damage zone and we have a outer damage zone. So, this more the fault propagates the width of the outer damage zone increases and if you see this part here the fault was initiated from this. So, this is the fault initiation zone and gradually the width of a damage zone it is increasing.

Similarly, depth wise if you are moving at the depth wise initial time. So, this was damage was very less and gradually once you are moving towards the propagating zone the damage in each increasing. So, here increasing the average compliance and increasing width of the outer damage zone in this direction and increasing along strength fault maturity that means this fault becomes more and more mature towards the initiation zone and the direction of long-term fault propogation and if you see this color it is increasing strength of the inter segment zone. Here we have inter segments zone so that means two fault sections they are overlapping in nature. So, here one segment is there relatively it is showing rotational deformation regime and if you are moving downward here that is the decreasing damage decreasing strength and similarly if you are moving in this way so this increasing strength of intersegment zone increases.

So, that means from this initiation zone towards the propagation zone the inter-segment zone's strength is increasing. Similarly, if you are moving from top to bottom the strength is decreasing. So, this is the general characteristics of anatomy of this continental lithospheric system around this continental transform fault. So, earthquakes along them it is reached up to depth of 20 kilometers but at places where this locking zone is there where there this hypocenters may be detected to a deeper level where there is a shortening exception shortening is there rare shortening is there locking is there where this transform fault depth or this related to this hypocenters depth it is more than 20 kilometer. Now you see this kinematic related to this continental transform fault here this is facing or this is a subduction zone which is facing this way and this subduction zone is facing in this way and they are facing in the same way this is the opposite way and this is the same way similar this is opposite way and this is the same way.

So, what kinematic is associated with that transform fault development. So now, if you see this kinematic rules of this plate tectonics commonly do not apply to them why because neither the plate is destroyed here nor it is created here so, that is why the general kinematics related to this other type of a plate boundary it is not applicable here and they all reflect the direction of relative plate motion, but they change their strike length depending upon the spreading and or migration of deformation along this boundary to connect it. So, if you remember our earlier class we were talking about somewhere this length may remain constant somewhere the length may decrease and somewhere the length may increase. So, that depends upon this condition the rate of movement and the rate of destruction or creation. So, some features related to this continental transform fault.

The continental transform fault leaves behind a tail zone. So, this tail zone means this is the inactive part where it was initiated and now become inactive so, that is called the tail zone. Such tail zones are not similar to the oceanic fracture zone but have fundamentally different tectonic characteristics. And where this continental transform faults are involved in triple junctions they commonly And where this continental transform faults are involved in triple junctions they commonly lead to the formation of a continental holes. So, it is continental hole we will discuss in the next slide.

So, resulting in the formation of incompatibility basins that means why it is called incompatibility basins because the basin is not long-lived that is incompatibility basin.

And the deformation is commonly distributed among the number of parallel to subparallel fault strands. So, already we have discussed here these deformations it is separated or it is distributed among different subparallel or parallel faults. So, once it is initiated with a point or line now the deformation zone is increased. And every fault it is showing a signs of deformation.

So, this total deformation around the zone it is divided into different fault segments parallel to subparallel with each other. So, now if you see this figure here we have different continental lithospheric system and there is a transform fault. So, now you see this segment how this transform fault is deforming and how this shape of this offset or this amount of offset is changing depending upon the direction. So, the continental transform fault owe to very low shear resistance of this continental crust and floatability of the continental lithosphere. So, that is developed where there is low shear resistance everywhere it cannot be developed.

Now here if you see this fault facing and this is the fault facing and this is the normal faults or the extension how they are facing. Somewhere this extension if you see here this is extending in this way and this fault is facing in this way this is the transform fault surface and if you see here gradually the length is decreasing because here it is normal fault here it is also not normal fault it is extending here extending and due to the extension gradually if you see the length of this transform fault it decreasing. So, it can be well explained when we are talking about this oceanic system. So, here due to movement towards each other so, the length of this transform fault is gradually decreasing. See the opposite may be true also.

At fault-fault-fault type of triple junction continental transform fault lead to the opening of lithospheric holes. What is lithospheric hole? We will see these figures that can be of either Karliova-type or it Kahramanmaras- type that depends on the geometry of this triple junction. The relative plate velocities and whether at least one plate is oceanic or not. For example, if you see here suppose A says before this onset of north-south shortening we have a circle here this north-south shortening is not there only we have 3 plates it is plate A and plate B and plate C and here we are putting a circle without any deformation without any movement.

Now let us compress it. So, here we are going from figure A to figure B now we are compressing it. Once we are compressing it what we are expecting that the deformation is there and the deformation is there in such a way that you see there is a strike-slip motion there is a separation that is lateral separation. So, though this is a compression, but here we are getting the lateral separation and this lateral separation it is creating a sedimentary basin here that is called lithospheric holes. So, here B after shortening this colored circles they are showing the zone of deformation. Now in the C this kind of triple junction both displaying as an asymmetric situations and in D resulting hole becomes asymmetric and some transpression component also in the southern boundary point.

Now here if you see suppose this is the plate A and B, C and we have a circle here now we are compressing it. So, once we are compressing it here some transform component is there some transpressional component is there. So, in both case we are compressing between A and B but this nature of deformation here and here are different. So, that's why there are two types of a transform for lithospheric transform fault like this is type and that type has been described. So, here at other type of triple junction here A is before this moment and B after the moment.

So, what the change we are getting after the moment. So, suppose this is separating that means C we are separating from here what we are getting we are getting a transform fault here we are getting a transform fault here so, here note that the while the C and A dash approach towards each other that means we are compressing the system but once we are compressing the system this B and B dash and A and A dash they are showing this lateral strike slip motion they are separating laterally. So, this is a special kind of transform fault which is of this type and Rtt it is representing the transtensional rift and F means this fault. So, here we are getting transtension, but other type here we are getting transpression. So, these either it is a transpression or a transtension.

So, we are getting sedimentary basins here these are called the lithospheric holes. So, earthquakes along this transform fault as we have discussed the maximum depth of 20 kilometer has been recorded. However, at certain places where this deeper locking is there this rigidity is there that is the earthquake depth may increase more than 20 kilometer. They are rarely confined to simple faults, but from broad zones of extensive fracturing containing commonly more than one major strike-slip fault thus forming a major keirogens. So, there are different type of terminologies that is using we have keirogens, we have orogens, then taphrogens.

So, keirogens are nothing this is the deformation which is formed by the strike-slip motion. So, the continental transform fault can be subdivided into three types. The first type is that those that connect to taphrogens, taphrogens means extensional basins. So, lithospheric structure formed from the large family of extensional structure that mean horst and grabens one extensional basin, rift basin is here another segment of the rift basin is here. So, it is joined by a transform fault that is called taphrogens.

taphrogens is the extensional basins. So, the extensional counterpart of this orogens. So, either the transform fault may divide or may join these two taphrogens that is the extensional basins and those that connect to orogens orogens means compressional system Himalayan orogens. So, compressional system that is collectively named for lithospheric structures that form along the convergent plate margins that is called orogens and those that connect an orogen with a taphrogen that means a converging system with a diverging system and although some of them are uncertain because the extreme complexity of the deformation areas they connect so, continental transform fault commonly do not obey the kinematic rules of plate tectonics because they do not create or do not destroy the lithosphere here. And the major continental strike-slip fault almost always occur it a system of a parallel fault creating broad zone of deformation. Already we have discussed they starting from a point or a line and gradually the zone of deformation increases.

And similarly if you see here this is a zone of around 150 kilometers. So, this transform fault the width can vary depending upon the age of the oceanic sorry age of this continental lithosphere involved. As we have example that we have this East African Rift Valley where this transform fault that is very narrow however in the San Andres fault it is representing a wide zone of deformation so, containing many individual strike-slip fault that is associated with the secondary structures. So, secondary structures that is either pull-apart basins or there will be a positive flower or negative flower structure that is divided. Here that means this triangle one is orogens one is taphrogen another is keirogen it is divided and this is the stretching axis.

So, you can divide this deformation system any of this segment depending upon their nature. So, it may be pure orogenic or may be pure keirogenic may be taphrogenic and in between that can be described depending upon either it is a strike-slip component with the strike-slip component normal component is there or it is a reverse component is there. So, the transform fault width remains narrow even below 20 kilometer because of the fact that the continental plates are transported along them without leaving behind their substrate reaching down to this 35 kilometer or more. Where these faults are short the penetration depth are also small.

So, it is proportional. The short length transform fault as a depth component is also very less. In such cases a large number of rigid semi-rigid block of thickness not exceeding the depth of Moho and commonly being restricted to the upper to middle crust take up the deformation so, in that case there are segments wise formation along this middle and the upper part of the crust which take up the deformation of this transform fault. And where it is a rigid transform fault it can move up to depth. Where is a long transform fault its depth component is also more. And in the continental crust the locus of the stretching in the zone of extension commonly migrate resulting from the asymmetry of this deformation.

If the two loci of the faulting move towards each other the transform fault becomes shorter that we have discussed earlier. In the deactivated zone a tail zone which is the damaged rock is left behind migrating the transform fault from T1 and T2. For example, if you see here how this length of the transform fault either increasing or decreasing or it is remain constant that has been explained here by taking this T1 and T2 as an examples. Here if they are moving towards each other it is decreasing length. So, in this way how this transform fault length will vary that it defines here.

So, thank you very much. We will meet in the next class with a new topic.