Plate Tectonics
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Week - 04
Lecture – 20
Propagating Rifts and Microplate Development

Ok friends, welcome to this class of Plate Tectonics. And in the last class if you remember, we are talking about these propagating rift and overlapping spreading centers. And we found this the rifts propagate towards each other and finally, due to this propagating it engulfs one segment of this oceanic lithosphere which experiences the rotational motion and finally, with time two segments of this propagating rift they join together and that's why this extension portion and one segment is abandoned. So, this is the along-axis segmentation of the oceanic rift system and in this class we are going to study about the propagating rifts and the microplate development. So, how these rifts propagate and how new micro lithospheric plate particularly the oceanic plates they developed and what is their dimension and what is their time duration where they existing and how they again merge with another plate. So, that will be discussed through different models that models has been proposed by different workers at different time and what are their advantage and disadvantage of different models and how the models could satisfy the actual observation in the field.

So, if you see this image we have a mid-oceanic ridge system and this magma is rising here and it is spreading to opposite direction. And if you remember our earlier class we are talking about this spreading system. So, we are talking about the Euler's pole and Euler's small circle Euler's equator like that. So, here we believe the transform fault that is the perpendicular to this spreading system they are representing the Euler's small circle.

And here this is the direction of this mid-oceanic ridge and the spreading is perpendicular to that. However, this spreading may or may not be perpendicular always to the long axis of this mid-oceanic ridge. So, the direction of spreading at an ocean ridge does not always remain constant over a long period of time and may undergo several small changes. For example, suppose we have a mid-oceanic ridge here and we believe this is the spreading system But with time the spreading center may change. So, once the spreading center is changing so that means we have reorientation of the ridge.

And once the reorientation of the ridge system changes similarly the overlapping spreading centers reorientation, the transform faults reorientation and the other component these volcanoes they are reoriented. So, that means, these different components of this spreading system they also reorient themselves. So, on the basis of the changes in the orientation of the major transform faults and the magnetic anomalies, it is observed that the spreading in the north eastern Pacific has changed direction in five times at least. So, that means, I want to say. Once we are having a mid-oceanic ridge system and this basaltic magma is pouring out and spreading and finally, these black and grey color segments they are nothing they are the magnetic anomalies.

So, if you go through this literature you will find we have the earth's ambient magnetic field. And during this volcanic eruption the magnetic minerals they freeze the magnetic field in the tiny magnetic particles at the magnetic minerals. And that's why we have positive negative magnetic field they are freezed in the basaltic rocks which is formed at the mid-oceanic ridge. So, now, if the orientation changes suppose this is the mid-oceanic ridge and parallel to that there were positive and negative this magnetic orientation. So, if this ridge is changing like this or reorienting like this so, that this magnetic reorientation also takes place.

So, that means, here if you see this is a transition between different segments different generations of magnetic anomalies. Anamlous topography associated with the oceanic fracture zone also suggest small changes in the spreading directions. So, this oceanic fracture zone or the transform faults they reorient themselves. So, that's why there is a topographic variation there is a geographic variation micro-topographic variation we found at the reoriented part of this oceanic fracture zones. So, then the ridge would be then lie at an angle to this original magnetic anomalies pattern.

So, if you see here suppose we have earlier ridge axis like this and now this is the magnetic lineations and if the reorientation of this ridge changes suppose now this is the orientation so, this magnetic lineations will be like that. So, that means, if this is the old spreading direction this is the mid-oceanic ridge this is the old spreading direction now this is the new spreading direction now we are getting new spreading direction. So, perpendicular to that we will have this transform fault like this isn't it. So, now, if you see here the reorientation of a ridge would take place by smooth continuous rotation of the individual ridge segments until they become orthogonal to the new spreading directions. For example, now suppose this is in case 1 this is the orientation of this mid-oceanic ridge.

Now with time the mid-oceanic ridge orientation wants to change in this way. So, that means, now this is the segment of this ridge now this segment has to reorient. That means, now you believe that this is segmenting into different parts. So, that this is the new ridge axis is reorienting with the preferred directions. So, with time again the spreading continues and this new ridge segments new magnetic anomalies they are formed which is parallel to the newly reoriented ridge segments.

Now the long portion of a ridge is affected in this way might be expected to develop into shorter lengths. So, facilitating ridge rotation and creating new transform fault for example, if you see we have a long orientation of the ridge suppose this is the length of this ridge now we want to reorient it. So, that means, we are segmenting into different small fractions and this small fractions now again this will be parallel to that. However, the change in the spreading direction is thus envisaged as a gradual, continuous rotation that produces a fan-like pattern of magnetic anomalies that vary with according to the position. So, now, if you believe that if this is the reoriented part.

So, what is happening this is again parallel to that. So, this will be parallel to that suppose again it is reoriented. So, then there will be an another type of another type of reoriented segment. So, finally, you are getting a fan shape that means, gradually rotating from its original orientation a fan-shaped magnetic lineations are developed, but what is happening here? Now suppose earlier this was the this is the ridge orientation now the new ridge orientation is here. Earlier these were the magnetic lineations now new magnetic lineations are there.

So, now, this old and new they are intervening here, but now you imagine suppose these regions these regions are nothing these were formed this newly formed and that's why it was not rigid. So, this newly oriented part of this or newly formed rocks they can reorient this segment and that's why this new "sorry" this is the new formed magnetic lineations and this old magnetic lineations they will merge here and there will be no strike continuity. So, due to this discontinuity of the strike we can say it is a fault but actually it is not a fault. So, that is why they are called pseudofaults. So, the propagating rift model it says that this alternatively suggest the changes in spreading direction and the creation of new spreading centers and its subsequent growth at the expense of the old ridges.

So, now, we have propagating rift systems. So, now, what is happening this new ridge is creating which is orienting itself and first second thing that this part is abandoned, but

it is not an easy thing. So, that's why there are different models have been proposed and these models will be discussed in the later times. Now, if you see if this was the old ridge and this is the new ridge. So, now, we have two different generations and two different oriented this materials that means, this magnetic strips they are oriented here.

So, thus the old doomed rift is progressively replaced by the propagating spreading centers orthogonal to the new spreading directions and the boundaries between the lithosphere it is formed at the old and new ridges they are called pseudofaults. Now, see this strike continuity here this is the strike continuity and this is the strike continuity. So, finally, the strikes are not matching. So, once the strikes are not matching at field we say it is an unconformity it is a fault so, here it is termed at a pseudofault actually it is not a fault there is no displacement However, this strike discontinuity is due to this reoriented magnetic strips due to the reorientation of this ridge system. Now, the pseudofaults it is defined a characteristics V-shaped wake pointing towards the direction of propagation.

Now, if you see this pseudofaults here and another pseudofault is here it is developing two other sides. So, they are merging together forming a V and the V is pointing towards the propagating system the direction of propagation. So, with that means, with time this way the ridge will propagate isn't it. So, this is the V direction that is indicating the direction of propagation. So, between this propagating and failing rifts lithosphere is progressively transferred from one plate to another plate and giving rise to a shear zone with a quite distinctive fabric so, this zone this is from new to old system this is representing a shear zone therefore, abrupt change in both the topographic and magnetic fabric of the sea floor occur at the pseudofaults and failed rifts and the new ridge propagates by the disruption of lithosphere formed by systematic accretion of the old ridge system.

So, now, here the old ridge system that was earlier in this way it is oriented. So, now, we have new "sorry" this old accredited system accredited margins are here. Now, you see this new one or the V-shaped is forming here the new propagating rift shifts here. So, now, we have different orientations here. So, in between these areas they are representing the pseudofaults which is separating these two and the new ridge propagates by the disruption of the lithosphere formed by the old system and particularly the degree of disruption that depends of the degree of consolidation particularly near to the ridge where the rocks were very hot and it was not consolidated these rocks will be more affected and the shearing effect is more prominent at near to that point and if you are going gradually away from the ridge gradually the degree of disruption decreases.

Now, here along this specific rise two figures are presented and if you see here this is the gravity anomaly and this is the magnetic strips. So, now, if you see here satellite gravity near the Iceland with an oversimplified "big V" you can see here because earlier this was the orientation of this mid-oceanic ridge and this was the magnetic strips. So, now, you see this is the orientation of the new ridge and finally, V is formed and is affecting the system this is the shear zone and here we have new magnetic strips are developed parallel to the ridge and we have old magnetic strips here and here we are getting these pseudofaults. Now, we have two models to define which model is the best-fitting to this observation in the field one is called the rotational model another is called the propagation model. Rotational model simply it is reorienting the ridge without much disruption.

However, propagation model it is ridge is propagating and part is abandoned and we are creating these pseudofaults here. So, this propagating rift it is associated with pseudofault concept. However, this rotational model it does not have any such pseudofault concept is here. Now talking about this propagating model it could give rise to evenly spaced fracture zones. So, now, we have different fracture zones.

So, this is the fracture zones generally evenly spaced. So, it can it could identify or it could explain how the evenly based fracture zones are developed and these new fracture zones are bounded by pseudofaults and or failed rifts because these fracture zones do not form until the propagation is complete. So, that's why this model the propagation model it could satisfy how these fracture zones are arranged in the mid-oceanic ridge or across the mid-oceanic ridge that could be that could be explained. Though this contrast with the ridge rotation model which does not produce failed rift and in which the fracture zones are areas of highly asymmetric seafloor spreading. So, this rotational model it has certain flaws that could that means it could not identify these observations or it could not explain properly these observations that how this ridge is rotating and how the fracture zone areas are highly asymmetric abundant ridges are there.

The propagation model predicts abrupt boundaries between the area of uniform magnetic anomalies and bathymetric trend of different orientation and the rotation model predicts a continuous fan-like configuration of magnetic anomalies whose direction change from the old to new spreading direction. So, these are different observations and different advantage and disadvantage of the different model like the propagation model and the rotational models. And the abrupt change in the direction of a seafloor fabric revealed by Sonar supporting the propagation rift model. So, that means, if you see here we have abrupt change in this magnetic anomalies then we are creating a V-shaped body

here and this observation and this model which is prepared by the propagating rift model they are matching. So, that's why the propagating rift model is best-fitting to the observation in the field rather the rotational model.

So, surveys around the west of the Galapagos suggest a new ridge is progressively breaking through this Cocos plate and the magnetic data in particular provide convincing evidence about the propagating ridge mechanism. So, this is all about what we have discussed here. So, this clearly revealed a V-shaped pattern of the pseudofault. Now, you can see here this is the V-shaped pattern and this is the pseudofault which is separating the earlier magnetic anomalies from the newer one. And the active and the failed rifts and the oblique tectonic fabric in the shear zone of the transfer lithosphere.

And this propagating rift model also elegantly explains the way in which the change in orientation of the Juan de Fuca fault and Juan de Fuca ridge has been archived and within this past 10 million years. So, if you can see here how this Juan de Fuca fault and this is the Juan de Fuca plate and this is the Pacific plate how the last 10 million years that has changed its orientation from one plate to another plate it is that means jumping. So, that could be explained by this propagating rift system. So, now, if you see here we have a cross-section from A to D and this is this one here and this is explained in terms of this magnetic strips of different time that has been expressed by the polar reversal time scale as year millions year ago here and with this different orientations are here and finally, we are getting a V-shaped body here and this is representing the pseudofault. So, it is assumed that the newly formed rift immediately attains the full accretion rate between the two plates thereby rendering the pre-existing rift redundant.

However, if the spreading on this new rift is initiated at a slow-rate and only gradually builds up to the full rate over a period of millions of years the failing rift continues to spread through at a slower and decreasing rate in order to maintain the new accretion rate. So, that means, it is a gradual process and maybe it is abrupt depending upon the geological condition and maybe gradual depending on the another set of geological conditions. So, if the spreading is a new rift is initiated in the slow rate then what will happen? Then only the gradually builds up the full rate over a period of millions of years and failing rift continues to spread and go at a slower rate and that is decreasing rate, but still in order to maintain the net accumulation rate net accretion rate. So, this is explained here how this different accretion rate different spreading rate it is engulfing a body which is in a rotating with time and a shear motion is experienced here. So, in contrast to this original propagating rift model in this model the two rift overlap at a area of oceanic lithosphere between them is increases with time and as a result of gradients in the spreading rate along each rift the block is intervening lithosphere is rotating.

So, now, if you see here we have this along strike and this is the transform fault are creating, but if it is a non-ridging transform fault is there this block is bounded and it is rotating. So, this is the computer simulation how the different spreading rate and with the spreading this propagating rift that is engulfing an area and how this stress system it is changing and how it is reorienting itself. So, this is a conceptual model at the top and the numerical model at the bottom it is showcasing three types of rift linkage. The connection one or this first one it is the connection of rift through an oblique fault it is small strike perpendicular to this offset and in the b at the transform connected to a rift offset at an intermediate offset and c this is formation of a continental microplate of the large 300 kilometer and initial of offset. So, that's why depending upon this offset here whether this microplate will develop or not developed that depends upon.

So, now, if you see we have this Euler's pole here and we have a spreading ridge here and we know from the Euler's equator to Euler's pole the rate of spreading, the velocity, linear velocity decreases. So, at time 0 if you see we have only a rift system just rift initiating and with time t1 this is the thin crust and finally, this is the rift basin and with time this is the rift basin is changing. So, now, you see how this system is going on along axis along strike gradients along the rift. So, here gradient is more here gradient is less and here it is less. So, this arrow that indicates the gradients that is at the more at the Euler's equator and the less at the Euler's pole.

Now, this rotation in turn produces the compression in the oceanic lithosphere adjacent to the tip of this propagating rift and a transtension in the region between the points where the propagating rift was initiated and the original rift started to fail. So, after a few millions years this transpression gives rise to the additional propagating rift. So, this is a continuous process for example, if you see here we have a propagating rift then with time we are abandoning it. So, with time again we are abandoning it finally, this area we are increasing here and with time this transpression what is doing it here it is creating another propagating rift. So, with time this is a continuous process it goes on and that's why if you remember our earlier class we have many abandoned propagating rift system that is lying around this transition zone.

So, this propagating rift model explains the formation of microplates in the South Pacific. We have this microplate here the Juan de Fuca fault and here we have that is Easter microplate here Juan de Fuca fault or Juan de Fuca plate So, these microplates they were either in this plate or that it becomes an independent plate sometimes it is merging with here sometimes it is merging with here. That depending upon this propagating rift the orientation of the propagating rift system. So, microplates thought

they are to exist for no more than 5 to 10 million years by which time the initial rift succeeds in transferring this oceanic lithosphere of this microplate from one plate to another. In the case of this Juan de Fuca fault or Juan de Fuca microplate this probably from the Nazca to Antarctic plate.

So, that means, this from Nazca plate to Antarctic plate. So, from Pacific plate so, this type this is jumping occurs and this jumping is nothing due to this propagating rift system. If a rift propagating in this way or the rift propagating in this way. So, this fault become a part of either here or this become here. So, this orientation of the rift the propagating orientation theory defines the microplate development and with time they merge with a larger plate or become independent for particular or for a few geological time scale.

So, this phenomena is not new and in the geological past such as microplate development has been reported. And, it is a common phenomena in ocean and the continental rift system and the microplate development and subsequent merging with time adjacent plate by propagating rift is found in the EPR and MAR. And therefore, it is believed that the spreading rate does not have any control over this phenomena. So, this is the orientation of this microplate, this is the orientation of the ridge with time that defines the microplate development rather the spreading rate it is defining. So, now if you see the cause of this initiation of the rift propagation is unknown but several researchers have noted that the propagating rift tend to form in the vicinity of hotspots and on the hotspot side of the pre-existing ridge crest.

We have different types of hotspots and we believe this the propagating rift they are occurring here. And most of these hotspots they have the evidences of the development of the propagating ridge system. And, if you see an important outcome of this mere existence of the propagating rift is that the ridge-push forces at the spreading center is not a primary driving mechanism as it appears to be quite easy overridden during the ridge propagation. So, if you see here this is ridge-push system that means when we are talking about this plate tectonics we talk about the ridge-push forces, slab pull forces so, at the ridge this pushing is dominant. So, due to this pushing this plate it contributes for the plate movement.

So, this ridge-push processes at the spreading center is not a primary driving mechanism as it appears to be quite easy overridden during the ridge propagation. So, this ridge during this ridge propagation this ridge-push forces it is in matters. So, that's why here some other driving force is responsible for this development of the microplate and the

development of this reorientation of this propagating rift. So, thank you very much. We will meet in the next class.