Plate Tectonics
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Week - 12
Lecture – 57
Continental Drift- I

Ok Friends, welcome to this class of plate tectonics and today we are going to discuss about continental drift. So, here the background of the study for this class is you have already been known about what is a continent and what is drift. So, the drift it is the starting from the rift and finally, it is coming to the drifting stage We are talking about this a rift basins is a divergent plate margin. In that class we have discussed briefly how a rift with time will reach to a drift environment. And rift that means we are stretching and drift means we already separated these two blocks or two continents and these two continents are now independent no link between them and they are moving opposite to each other that is drifting.

So, this terminology says the continental drift that means continents they are moving or they are drifting. So, this idea of this continental drift it was proposed by this German explorer that is Alfred Wegener in 1912. And Wegener hypothesized this by looking through the different large landmasses that as if you see here this Africa and this is South America the age of these two continents they are matching. So, by looking this similarity of their age first he proposed that once upon a time these two continents and other continents similarly they were united together and with time they separated or that means they drifted apart from each other.

So, this is like this fitting together in a jigsaw puzzle manner how these two continents are matching. And this continental shelf of Americas fit closely to the Africa and Europe and Antarctica, Australia, India and Madagascar fit next to the tip of South Africa. This was the observation by Alfred Wegener. And in 1912 Wegener proposed this theory which hypothesized that continents were slowly drifting around the earth. And this hypothesis in 1912 he publicly advocated this continental drift arguing that all the continents were once joined together in a single landmass and they drifted apart.

And though he proposed this theory but satisfactorily he could not explain what exactly the reason behind it. Though these continents were once upon a time they are together

and they are separated but what is the force behind it, what is the mechanism behind it by which they separated. So, at that time he supposed the cause might be the centrifugal force of this earth rotation or this astronomical precision. So, at that understanding of that time and he proposed this is probably the centrifugal force is responsible for this type of drifting apart of this continent. And once he published it, one American edition of Wegener's work published in 1928 and this was received very poor attention and American Association of Petroleum Geologists organized a special symposium specifically to oppose this continental drift hypothesis.

And this Alfred Wegener's hypothesis if you see this map he was showing that these are the matching part of this continent and these continents are drifting. And he hypothesized this concept based on the observation of its shape, their fossil content, their climate and their rock types. So these are the four parameters he used to prove his theory, yes the continents have drifted apart and his hypothesis was controversial and not widely accepted up to 1950s. So now imagine around 40 years he argued continuously that is continental drift was there but no one believed it and specially this AAPG people, this American Association of Petroleum Geologists that means sharply, they criticized Alfred Wegner's hypothesis and special symposium was called to oppose his theory So why people believed and what was the proof which was not enough to support this theory? It says that these people believed because Wegener's continental drift theory was not readily accepted by the science community of that day and it was difficult to conceive of large continents ploughing through the sea floor to move new locations. This was the main drawback how a large continent of several lakhs of square kilometer area, how it could ploughing through this ocean floor and what kind of forces could be strong enough to move such large mass of solid rock over such great distance.

So at that time there was just the initiation of plate tectonics theory even if you can say there was no plate tectonics theory because plate tectonics theory it was introduced in 1960 and this I am discussing about pre 1960s around 1912 to 1950 around 40 years before this plate tectonics theory was introduced. So in that case that is why he was not able to understand, he was not able to explain why this force and which force is responsible for drifting those continents from one place to another place of 1000s kilometer apart. So that was the main drawback that is why people was not able to accept this theory at that time. And he analyzed either side of the Atlantic Ocean on their rock types, their geological structures, their fossil content and noticed that there was a significant similarity between matching sites of this continent especially the fossil plants. So if you see this figure here these are the distribution of this fossil plant and you can see this South America, Africa, India, Australia and all those, these fossil plants were distributed in this region.

Similarly if you see this Mesosaurus and other fossils they are also distributing in particular area which is now across this continent. Isn't it? So first he hypothesized this based on this fossil content and his hypothesis was the strongly supported by the physical evidence and was a pioneering attempt to rationalize the explanation. So if you see here before he proposed that these continents were united together and now these are somehow separated of 1000s of kilometer apart. And this application of paleomagnetism it is one of the strongest supporter of plate tectonics, and it is not only qualitative supporter it is the quantitative supporter that means this plate motion, this time based plate motion that can be determined by this paleomagnetic behavior of these rocks. So this paleomagnetism when it was introduced in 1950 and 1960 it provided the first quantitative evidence that continents had moved at least in the north-south direction.

Why north-south direction? Because magnetism always talking about north-south that is magnetic north-south not geographic north-south and at least the change in this paleomagnetic behavior of rock that can suggest that at least this continent or this piece of land had drifted around north and south direction. So this paleomagnetism at the first time it provided the quantitative evidence about this continental drift theory. Moreover it was demonstrated that this continents had undergone relative motion and it is confirmed that continent drift has actually occurred. So this relative motion already we have discussed relative plate motions and also absolute plate motions is there so it will be taught when we are talking about this GPS and plate tectonics. So Alfred Wegener called this large landmass that is called Pangea that is all land and which was separated to this present plate landmass.

So here if you see this distribution of Pangea so that means all this continental mass that were placed at one place and that is called all land and with time they are separated. So now you can see this is South America, Africa, India, Madagascar all those they are separated. And that time that Pangea was proposed by Alfred Wegener but later on with the more and more research with the paleomagnetic and precise dating techniques so help of these there are number of supercontinent that has also been established. So these are the geological time and the name of this super continents are given here and this says that it is not the Pangea is the only supercontinent it was existing before that there are number of supercontinent that was been established and every time the supercontinent that means it is amalgam of different continents that occurred and with time again separated. So it is a cyclic process.

So with time this separation is different. So that means when this Pangea was existing here it separated to different land masses and there are land at sea distribution are

different. Similarly when Rodinia was there the land and sea distribution was different so that means I want to say there are number of times the paleogeography of this earth has changed and in geological future also the paleogeography will change it is a continuous process. So this supercontinent cycle if you remember when earlier class we were talking about supercontinent cycle and Wilson cycle. So the supercontinent cycle it says number of times the continents are clubbed together and separated.

So this is same thing is happening and this Alfred Wegener he proposed this existence of this Pangea. So now the question arises what is the evidence? We are talking about yes continental drifting is there so what is the evidences for that? So first it is the geometric reconstruction of continent geometrically matching so that means the edge matching. So it is the approximate reconstruction were performed manually by moving models of this continent across but an accurately constructed globe were performed mathematically by computer using different computer program to minimize the degree of misfit between the juxtaposed continental margin. So instead of this coastline the true junction between the continent and the oceanic lithosphere was taken for matching. Here you have to understand this science behind it.

So you see the coastline suppose for example this is the coastline of Africa and this is coastline of America we can go for matching. But why this coastline were ignored and instead we are taking a point which is the junction between this continental and oceanic lithosphere that means instead of coastline here we are matching a place where this continental and oceanic lithosphere they are meeting. That means we are going to this continental slope region. The reason being this coastline it is a changing process every minute every day that means every month or twice a month this coastline it is shifting. In addition to that we have recorded number of time there are climate change there are tectonics so that this coastline due to marine transgression and regression it has shifted either continental or it is towards ocean world.

So that means if we are taking this is the reference point so it is not constant point. So that is why for matching we need a constant point. So this is the constant point where this continental lithosphere and the oceanic lithosphere they are welded together that is the continental slope. So that is why instead of taking this coastline as a marker we are taking this continental slope as a marker so that this is a fixed point and it will never change. So by matching this continental slope or this continental slope region or this region of one continent to another continent it was found that there was some matching that means some overlapping and some deficiency.

That means somewhere this continental slope or this region of matching that is

overlapping and somewhere it is not exactly matching there are some deficiencies. So why this is happening? So the first mathematical reassembly of continent it was solely based on geometric criteria it was performed by Bullard who fitted together these continents on either side of this Atlantic because it is the most precisely matching and Atlantic Ocean you know this is the youngest one among the oceans. So most of these evidences of the recent past it been preserved here so that is why most of this matching it was performed across this Atlantic system. And this was accomplished by sequential fitting pairs of continents after determined their best-fitting poles of rotation. Poles of rotation we know when we are talking about the Euler's pole so simply it is rotating and not just it is a linear moment it is a rotational moment.

That is why when we are going for matching of this continent we must take care of this a rotational system rather a linear moment. So if you see during this matching we have some overlap area this red color it is marked by some overlap area. So number of overlaps of geological significance may be related to these processes of stretching and thinning during formation of this rifted continental margin. You can remember when we were talking about the ripped basin we were talking about the divergent plate margin before this that may be formation of the divergent plate margin or the mediasnic system the continent is stretched. So normal faults or the series of normal faults were developed.

So due to stretching this continental slope or this boundary between this shelf and slope this is the continental lithosphere and the oceanic lithosphere it has some disturbances. So that is why this overlap can be explained by such stretching during this continental rifting. And fitting of this continental edge of the east coast of Africa, Madagascar, India, Australia and Antarctica has been confirmed that by subsequent analysis of the record of magnetic lineations in the Indian Ocean and the presence of Gondwana land was confirmed. So here you can say this is the magnetic lineation that is another term we are using. So in detail what is the magnetic lineation and how it is used in continental drift theory we will take a separate class for that.

At this stage you see just when there will be a mid-oceanic ridge system and we know this basalt is continuously pouring out and this basalt it is containing the ferromagnesian minerals and when this basalt is coming out or it is forming at the mid-oceanic ridge and this ferromagnesian minerals they freeze their magnetic field according to this earth's existing magnetic field. For example, suppose we have a globe and we have north-south magnet, so this magnetic lines of force. So when we are creating a rock here igneous rock or sedimentary rock when it is depositing particularly the fine-grained sedimentary rocks, so they align according to this earth's existing magnetic field and this magnetic properties of this rock or the small particles they are aligning with the existing earth's

magnetic field. So similarly when there is igneous rock which is forming at the mid-oceanic ridge system the ferromagnesian minerals when they are cooling below this Curie point, so they are aligning themselves with the existing earth's magnetic field. And this black and white strips they are nothing they are the normal and reverse magnetization.

Normal reverse magnetization you know this when the geographic north and the magnetic north they are in the same direction we say it is normally magnetized and when the opposite direction we say it reverse magnetized because earth's geographic north and south are fix. But many times the earth has recorded that the reversal of magnetism that means the north pole become south and south pole become north and in that case so reverse magnetization occurs. So, that is why this carpet of basalt which is forming from the mid-oceanic ridge can be divided into different strips of different thickness or different width depending upon the time frame or depending upon the duration of normal magnetization and reverse magnetization and depending upon the rate of seafloor spreading. So this basaltic carpet can be divided or can be colored with black and white strips depending upon its width of this normal and reverse magnetization. And this magnetic lineations or this magnetic strips that gives the quantitative evidences of this continental drift.

So detail about this magnetic lineations and this is magnetic field in the basalt and sediments and other type of magnetization we will take another class and separate class we will discuss. So at this stage just you remember so these are these fundamental behind this magnetization and this magnetic lineations. So this continent when they are separated apart when we are forming this mid-oceanic ridge system there that means these magnetic minerals they are forming here they are aligned themselves with the existing magnetic field and it is helping to understand or to define this continental drift theory. So another evidences that is called the geological evidences it says matching of the geological features across the supercontinent. For example if you see we have this Appalachian mountain system we have the Caledonian mountain system.

Here the Appalachians and this is the Caledonian. So here you see this Appalachian fold belt and the Caledonian fold belt once of in a geological past they were together. So two mountain systems now thousands of kilometer apart but if you see this across this Atlantic in geological past they were together. So it was one mountain belt due to this drifting of this continent due to this rift they are now separated and one is in Africa another is in Europe. So this continuity of Appalachian fold belt in the eastern North America and Caledonian fold belt in North Europe so now they are separated.

And composition, grain size and age distribution of zircon grains in these sediments

suggest the source of sediment in the Caledonians of this northern Europe lies west in the location now occupied by the Atlantic indicating that in the past this location must have been occupied by this continental crust. So now imagine we have two continents if you are taking back to their original position they were welded here and we have this Caledonian mountain here and we have Appalachian mountain here. So we have this Atlantic in between. Now you remove the Atlantic that means you remove some time from the geological time scale. So now what is happening we are taking its back.

So once we are taking its back it will become one mountain belt and this is very interesting to say this zircon grains were collected from both of these mountain systems and it is found that time their source is from this continent and once upon a time it was somewhere here. So that means the source was here that means it was occupied by a continental system and it was providing sediment for these basins and those sediments they are crumpled and they reactivated in this mobile belt and forming this mountain chain and further with a rifting apart or drifting apart they form two separate mountain belts. Then age province if you see here the correlation of ages across the southern Atlantic which illustrates the matching of both Precambrian cratons and the rocks of the Paleozoic era. So here if you see how this Atlantic system was developed with time we have a rift basin first developed and with rift basin it was occupied by the marine system and finally full-fledged Atlantic was developed. So now imagine when this was a basin which was receiving sediment from the both side so we have a sedimentary basins now we separated and we made it two different places two different pieces and the age of deposition or the age of rock from both side becomes same because they are deposited at the same time.

So that is why this age belt or the age province across this Atlantic it says that once upon a time they were deposited at one time and one place and now separated. Similarly we have this Archean cratons and this mobile belt, Proterozoic mobile belt. So this Proterozoic mobile belt and Archean craton it says that was activated at the same time and that was existing at the same time and now they are separated thousands of kilometers apart. So, that means the age province also it is supporting that once upon a geological past these continents were together and finally it gets separated with time. Then igneous province, igneous province that means if you see here this map which is showing Mesozoic dolerite so distribution and this Precambrian anorthosite these are the Precambrian anorthosite dikes or anorthositic emplacement and you see this province once upon a time once united and these rock types were emplaced there.

So now they are separated and distinctive igneous rocks can be traced between this continent both to extrusive and intrusive rocks and such as the belt of Mesozoic dolerite

which extends through southern Africa, Antarctica, Tasmania and approximately linear trend of Precambrian anorthosite through Africa, Madagascar and India. So if you go to south India particularly the peninsular system you will find kilometers length anorthosite dike and there are nothing it is during this supercontinent that was formed that time and now they are separated. So these are these evidences that are now available to predict or to convince yes once upon a time these continents were united together and with time they separated. So this is the discussion about this continental drift and we will continue this discussion in further. So thank you very much and we will meet again.