Geomorphic Processes: Landforms and Landscapes
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Module No # 03
Lecture No # 14
Interior of the Earth & Plate Tectonics (Part V)

Welcome back so in last lecture we were discussing about that how the Himalaya was formed and we also discussed the 3 possibilities or the 3 cartoons which are right on your screen which shows that how the continental plate was (00:43) or override the oceanic plate first. So initially the Indian plate was having the oceanic plate in front of it and then when subduction started taking place when there was volcanic eruption because as we have discussed in the previous lecture that when there is a subduction of one plate beneath the another one there will be melting which will result into the formation of volcanoes on the overriding plate.

And then there was a closure of Tethys Sea which is existed between the Indian plate and the overriding Eurasian plate. So the Indian plates subducted below because it had an oceanic plate before at and then the closure resulted into the collision between the oceanic plate between the continental plate and continental plate. Because both the continental plate collided and because of the collision what we see today is the mighty Himalayas.

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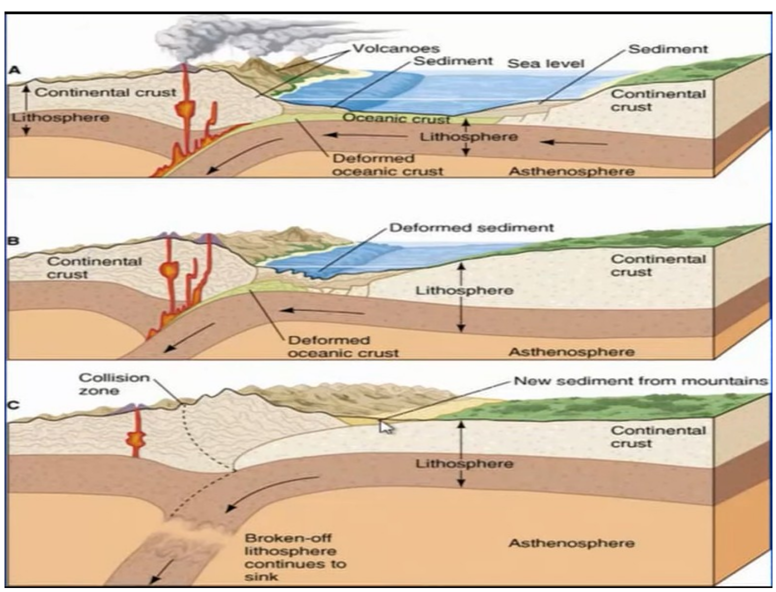

Now there is no more see if you look at the this 3 cartoons which shows that the initially the oceanic plate which was ahead of the continental plate or that is the Indian plate subducted beneath the continental plate of Eurasia resulted in to the volcanic erosion on the overriding plate and then there was this between this 2 plates there was a Tethys sea which slowly started closing up and the collision between finally between the 2 continental plate resulted into the buckling up and folding of the sediments resulting into the formation of the folded Himalayan belt.

So the since there was no more supply of the oceanic plate or any plate beneath into the asthenosphere the volcanic activity seized. So no more volcanic activity now we can see what we see is the formation of the towering height of Himalayas the mighty Himalayas and in the frontal part of the Himalaya that is to the south of Himalaya along the plate margin we have a basin which was formed and that what we see in the Indo Gangetic plain.

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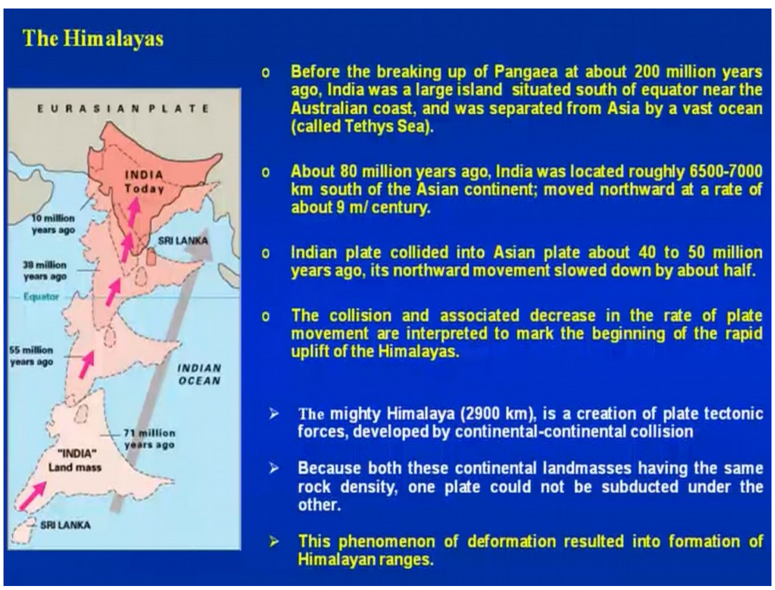

So basically, the Indian plate was located far south of equator when it started its journey. Then initially it started its journey in this direction and slowly it changed toward the present and collided with the Eurasian plate. So right now, the motion is almost north-north east in the north-north east direction. So before the breaking up of Pangaea at about 2 million years ago, India was a large island situated south of the equator near the Australian coast and this was as you remember was the part of the Gondwanaland.

About 80 million years ago India was located roughly 6500 to 7000 km south of Asian continent and moved at the rate of almost 9 meter per century. It is believed that the Indian plate collided with the Asian or Eurasian plate at about 40 to 50 million years ago, its northward movement slow down. So during this time when there was a collision at about 40 to 50 million years ago its speed or the movement of the velocity slow down at this was because of the collision.

And the collision resulted into the decrease in rate of the plate motion and it is interpreted as this was the time when the rapid uplift started of the sediments resulting into the formation of Himalayas. So the mighty Himalaya which covers the distance from east to west about 2900 kilometer is a creation of plate tectonics forces developed by continental-continental collision. But please remember that initially there was a subduction between the continental plate and the oceanic plate which was ahead of or in the front of the Indian plate.

Now because both the land mass that is the continental land masses having the same rock density one plate could not be subducted under the another one. This phenomenon of deformation resulted in the formation of Himalayan.

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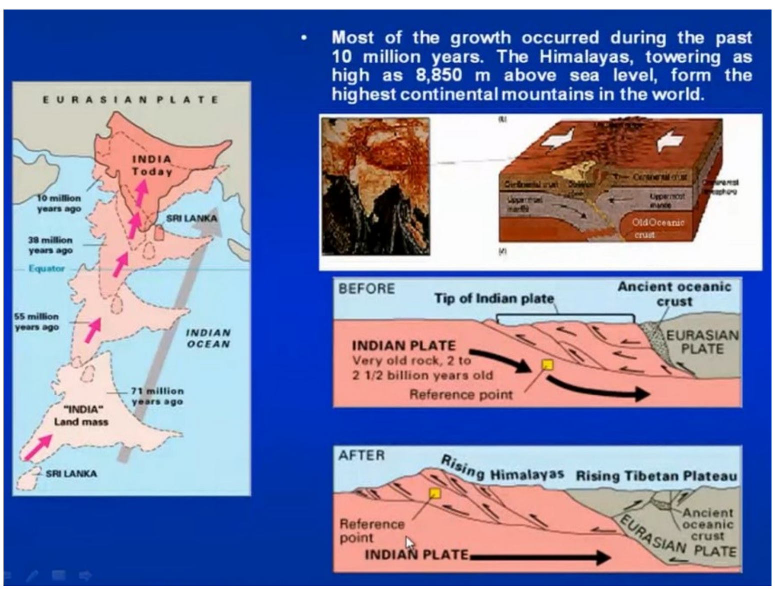

So the height of the highest point in Himalayas is we know is Mount Everest which is almost 8,850 meters. So this is the configuration that the Himalaya is rising and there is several fall plains along which movement is taking place over the in the land mass which is overriding these subducting Indian plate or the plate which is initially subducted below the Eurasian plate.

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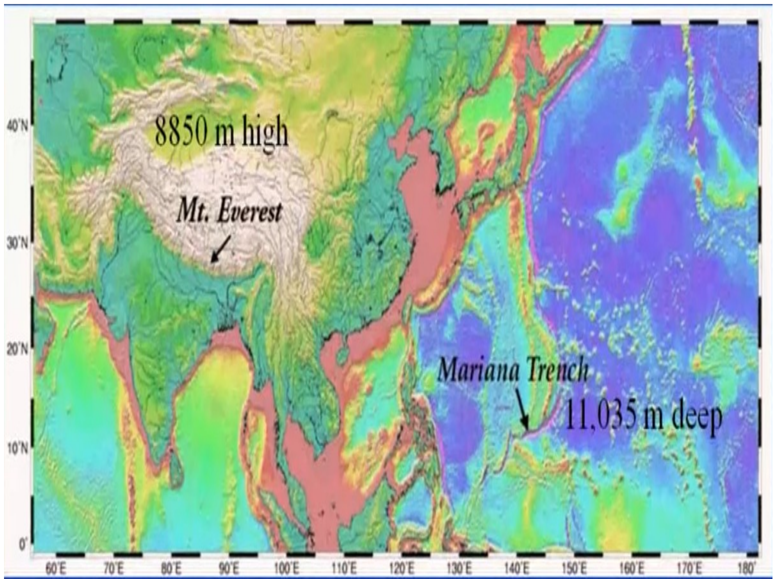

So the highest point and the deepest part is the highest point on the earth is Mount Everest and the deepest ocean on the earth is Mariana Trench.

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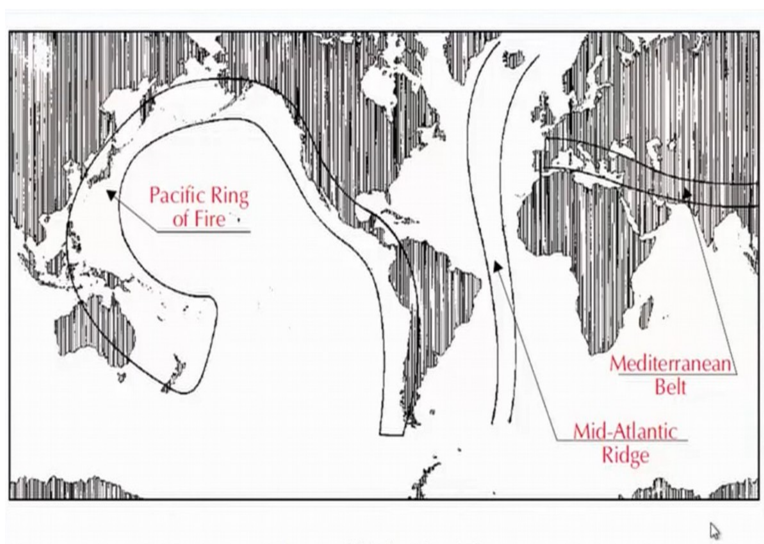

Areas of high seismicity.

An another important features which shows the areas of high seismicity are the Mediterranean Himalayan belt which is located here then you have the mid oceanic ridges or mid Atlantic ridges and then the you have the ring of fire.

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Some few some facts of the Himalayan origini is that we have almost like 2000 kilometer long to 2900 kilometer long Himalayan range and this portion which is marked by arrow marks the contact between the 2 plates or the plate boundary active plate boundaries between the Indian plates and the Eurasian plate.

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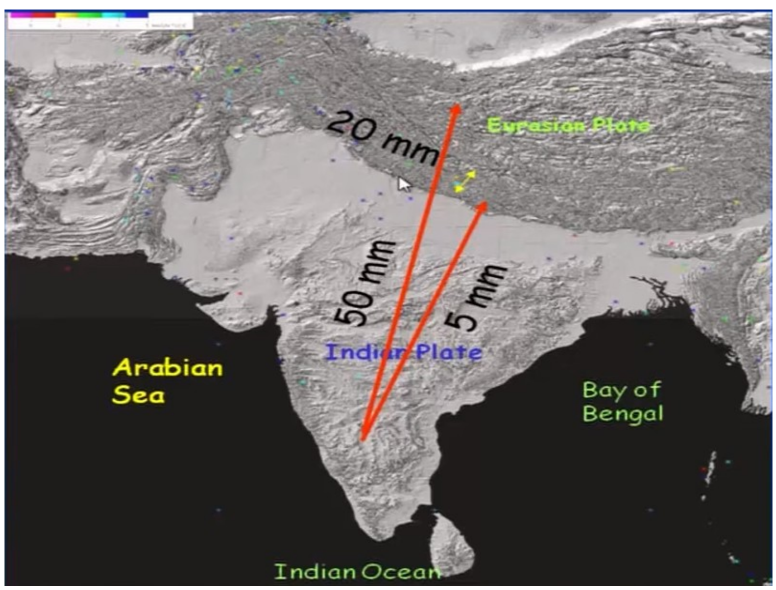

So the GPS measurements from south India that is from Bangalore keeping the Eurasian plate fixed it shows that the movement is almost around 50 millimeter per year. So India is moving towards Eurasia within the velocity of 50 millimeter per year and out of this up to the frontal part of the Himalayas or at the contact of this 2 plates that is the Indian plates and the Eurasian plate it consumes hardly 5 millimeter per year.

So 5 millimeter per year out of 50 millimeter is been consumed by entire Indian plate where is the consumption across the Himalaya which we can say that this is the collision zone where 2 plates are colliding it is maximum of 20 millimeter per year. Now I will discuss some slides very quickly because this gigantic land scape which is the result of the collision of 2 plate that is a landform which also not only results into the formation of the mighty drainage basin in India or Indian subcontinent.

But also this is the location which results or leads to the hazard in this region or hazard to the entire Indian plate. So this movement or the velocity which is been shown here as 50 millimeter and 20 millimeter across Himalaya in a very short portion as compared to both you see the 50 millimeter the formation. This area is under high strain and responsible for triggering large magnitude earthquakes in past and in future also.

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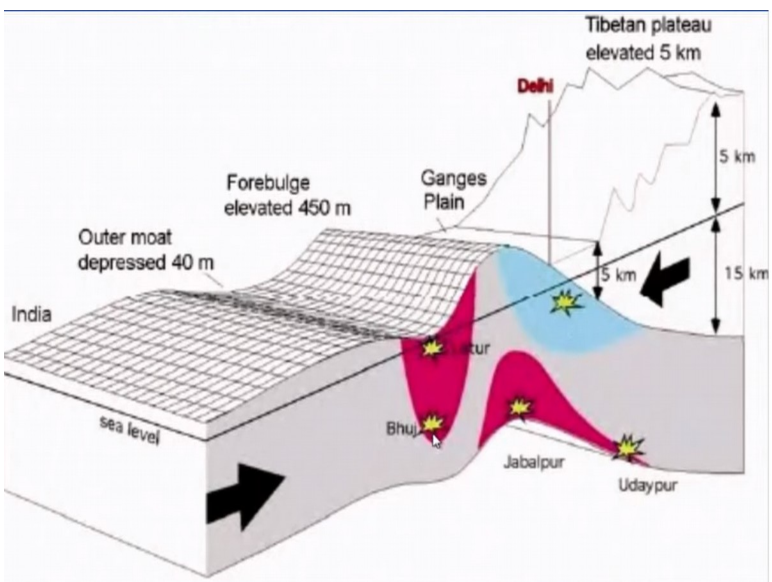

So whole plate is under deformation, so this is at the place of the contact between the Indian plate and the Eurasian plate and rest of the plate region is also under deformation and slowly flexing up. So many earthquakes are seen or observed along the plate boundary and away from plate boundary also which have been listed here this was 2001 earthquake and this was in 1995 or so or 1997 Jabalpur earthquake and so on.

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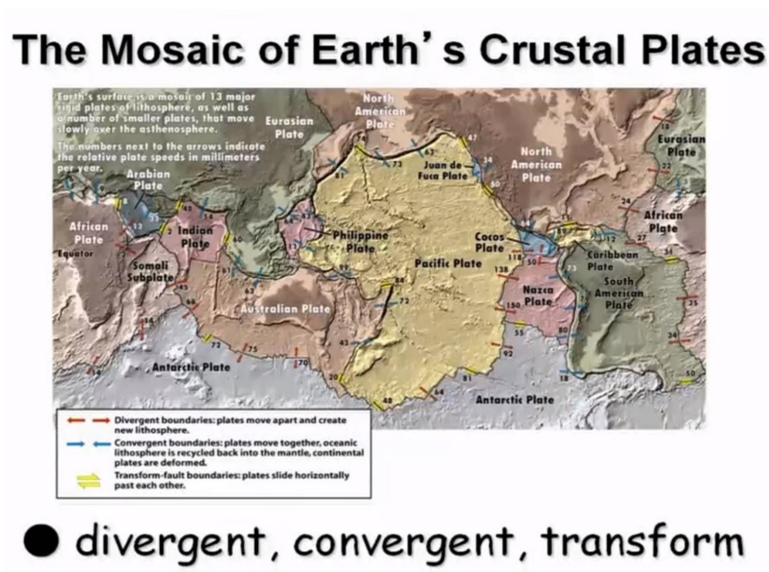

Now configuration of the tectonic plates if you look at the mosaic of earth crustal plates, we have dozens of plates which are seen or observed on the globe. And they are either colliding with respective one another passing by each other resulting into the formation of lateral faults system or subduction zones subduction plate boundary as we have discussed between the Nazca plate and the South American plate or we are having the collision boundary which we see between the Indian plate and the Eurasian plate.

And in short what we learn that we have 3 type of plate boundaries one is divergent plate boundary and another is convergent plate boundary and third one is transform plate boundary.

And along the transform plate boundary nothing is broken along the convergent plate boundary the plate is destroyed hence it is also termed as the destructive plate boundaries. Whereas in terms of the horizontal in terms of the transform plate boundaries there is an horizontal slide where 2 plates pass each other.

And the divergent plate boundary the new plate is been added or the new lithosphere is been created as the plate move away from one another and magma is been poured on the surface. So the mosaic of rigid plates (()) (13:57) 3 type boundaries so we have divergent, convergent, transform.

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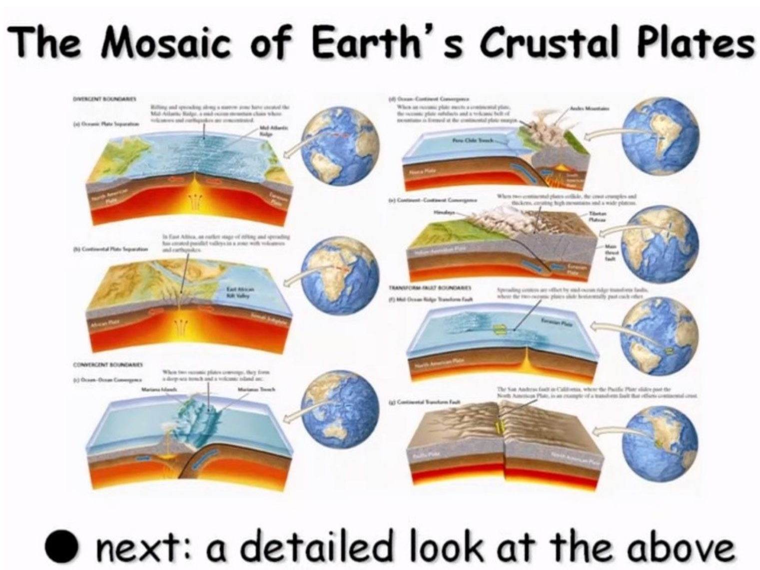

These are the sample for it where we have discussed in detail about the splitting centers about the collision zones and about the subduction zones.

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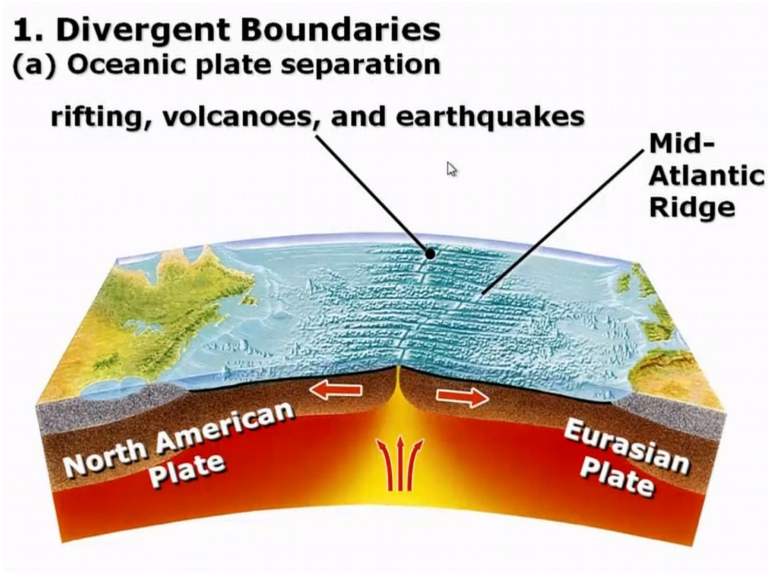

So one is the divergent plate boundary and this are been seen which encircle the earth right from South Pole to north is the mid oceanic ridge or mid Atlantic ridge. And this results into the landforms which we see as rifting or rifts in volcanoes and associated hazard which is been created is basically the earthquakes.

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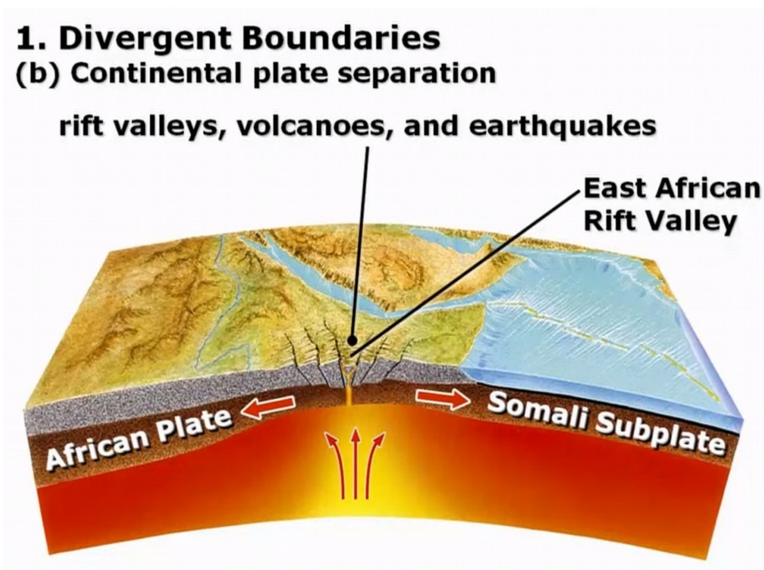

Then we have divergent plate boundaries where we have plume where the 2 plates are moving away from one another as we see in case of East African rift valley and one example we discussed about the current separation and the formation of huge wide crack in the African East valley which is the clear cut example of the split up of the highland. So rift valley, volcanoes and associated earthquakes.

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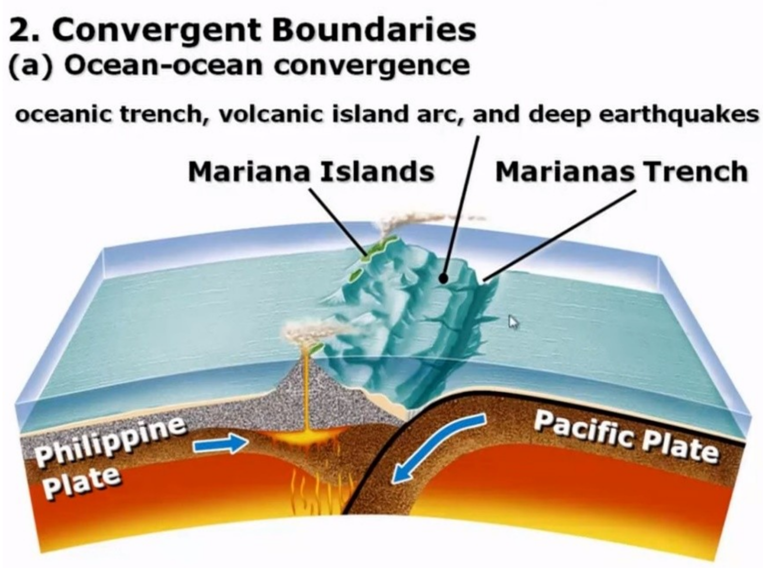

And the deepest part between the pacific plate and the Philippine plate is mark by trench and which is around 11,035 meter deep termed as Marianas trench. So this are the features which are commonly seen when the oceanic plate subduct below the oceanic plate so we have deep trenches even the and the earthquakes which will be triggered here will be deep as well as shallow and then we will have volcanic arc on the overriding plate and the trenches between the contact between the 2 that is the contact between the 2 plates.

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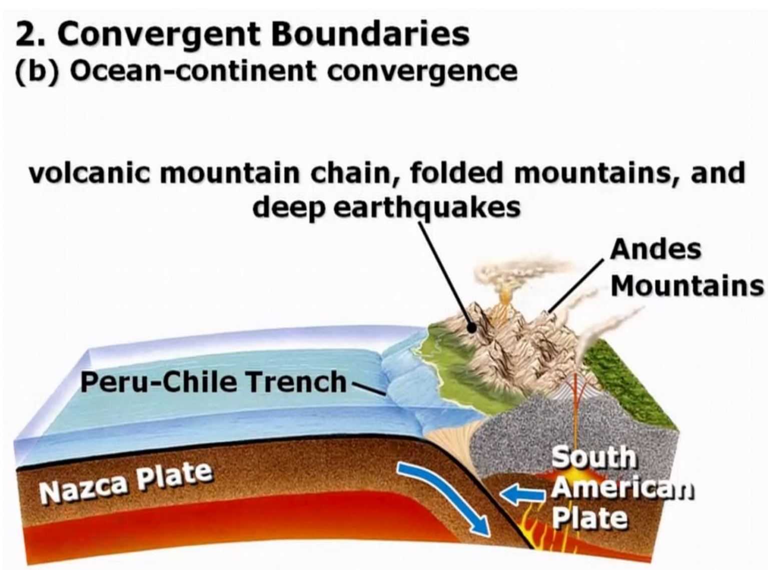

So the deepest trench on earth then again another convergent plate boundary is your where the oceanic plates subduct below the continental plate the example is the volcanic eruption on the south American plate side and formation of the Andes mountains. So volcanic mountain chain, folded mountains, and deeper earthquakes is the shallow earthquakes will be experienced in this region.

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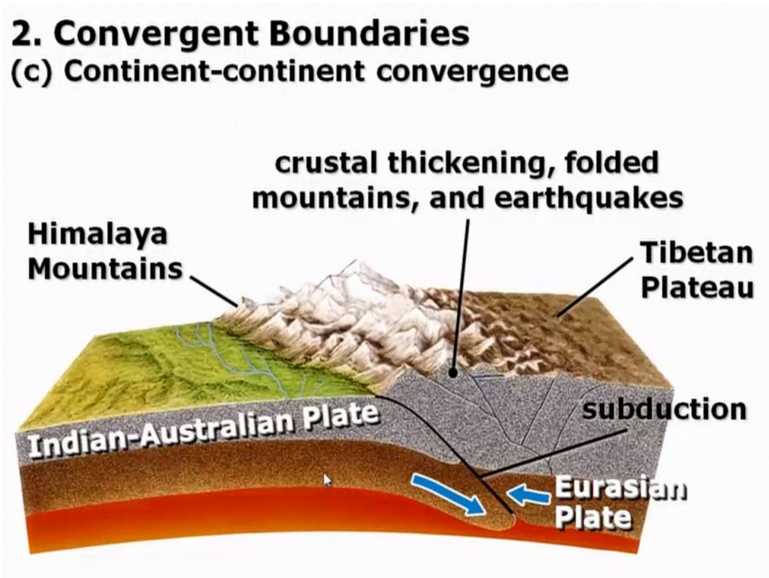

Then comes the continental-continental convergence best example of this convergence is Himalayas. And as we discussed way back in the beginning that this will result into the crustal thickening, folded mountains and the shallow earthquakes. So this is an example between the Indian plate and the Eurasian plate. Where the Eurasian plate is overriding the Indian plate because initially the Indian plate which had an oceanic plate in front subducted below the Eurasian plate.

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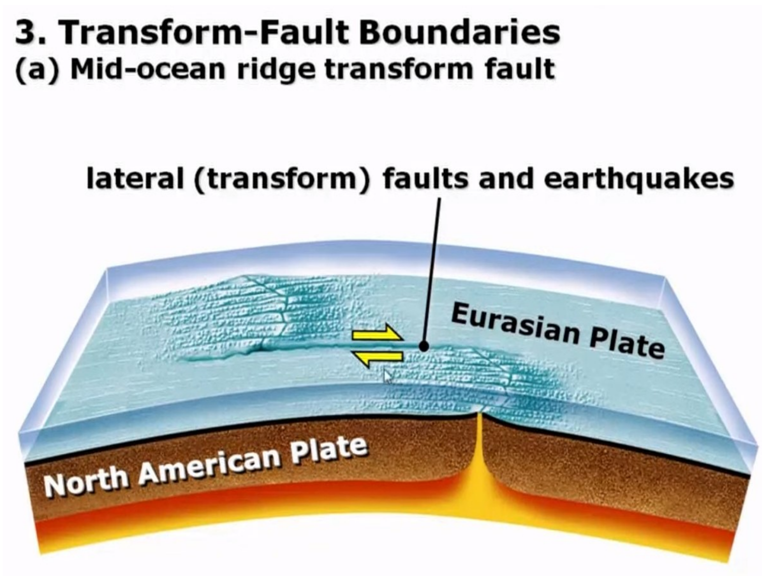

Then comes the transform plate boundaries for example which exists along the mid-Atlantic ridge or mid oceanic ridge and this lateral faults or transform faults also triggers earthquakes along it. So this are the spreading center which have been shown here. Now the movement if you take this as an piercing point it is opposite for what it has been seen here.

But the movement which is shown here is based on the movement of this portion of the plate because from the center here where I am putting my cursor this portion of the plate is moving in this direction and with this the portion the movement is in this direction. Hence along this fault or the transform plate boundary the movement is in this direction and this side in this direction. So on your right the movement is towards you and on your left the movement is away from you.

And this type of movement is termed as right lateral movement. But if you take this piercing point this spreading center the movement is opposite because this portion as it is located here, and this portion is located here so the direction is in opposite to what you see here. So do not confuse between the direction which is been shown here. But the actual feedback which you should take from this which is the correct direction of motion along this transform fault.

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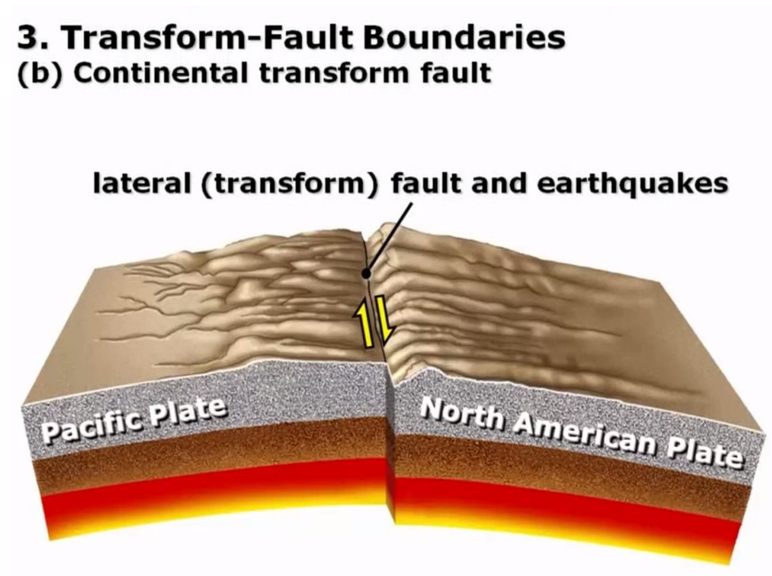

Again transform fault plate boundaries one of the best example is between the pacific plate and north American plate where the 2 plates are moving along and or showing the horizontal movement and of course with an oblige slip it also has resulted into the formation of the mountains along the plate margin. And this movement is what we see is right lateral. So again, lateral or the transform faults and will we definitely associated with earthquakes.

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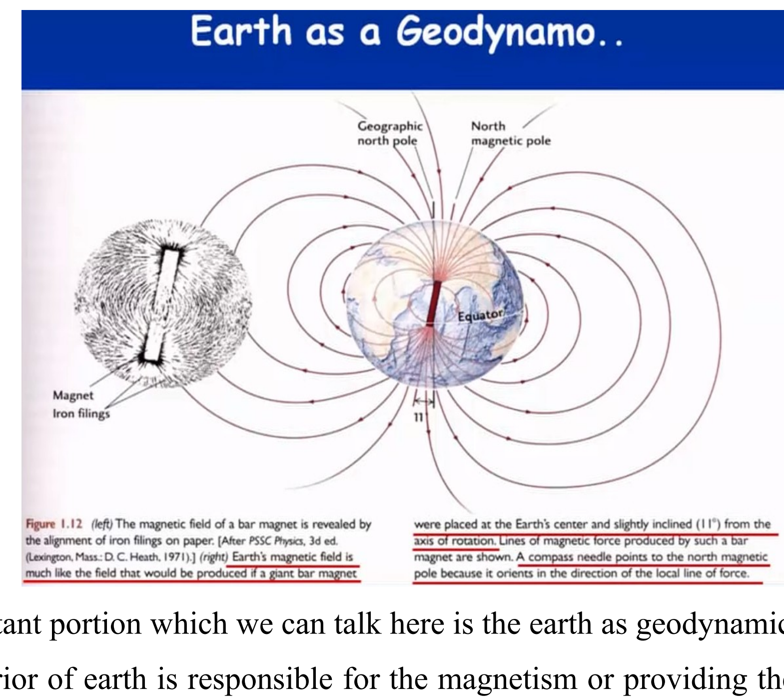

Now very important portion which we can talk here is the earth as geodynamic. Now which layer in mean the interior of earth is responsible for the magnetism or providing the magnetism or act is in geo dynamo which keep generating the convection current and which helps the earth to rotate. So this is very important, so earth has geo dynamo. Let us look at the few slides and try to understand that the interior of earth that is the outer core which is liquid is responsible for the magnetic field of the earth and this is very important.

And why it is so that the liquid the outer core is liquid and the inner core is solid. So this we will discuss in few slides. So if you see here the north magnetic pole and the geographic North Pole they are about 11 degree apart and the North Pole is incline towards or north magnetic pole is incline towards east with respect to the geographic north. Geographic north is almost what we say north south. But the north magnetic pole is 11 degree inclined towards east. So the earth act as an large bar magnet bar.

So the earth magnetic field is much like the field that would be produced if a giant magnet where placed at the earths center and slightly inclined that is 11 degree from the axis of rotation. So the earth magnetic field will act as an huge or giant magnetic bar if it is been kept 11 degree inclined from the geographic north. So the line of magnetic force is produces by such a bar magnet are shown as it is been shown here at it moves from here and get in to this ok.

So this is the magnetic forces and a compass needle points to the north magnetic pole because it orients in the direction of local line of forces. So for the force which is acting in this direction along the 11 degree incline magnetic bar. The needle of the compass will also aligned along the magnetic pole or the magnetic. So the compass needle points to north magnetic pole because it orients in the direction of local line of forces so this is what we are discussing.

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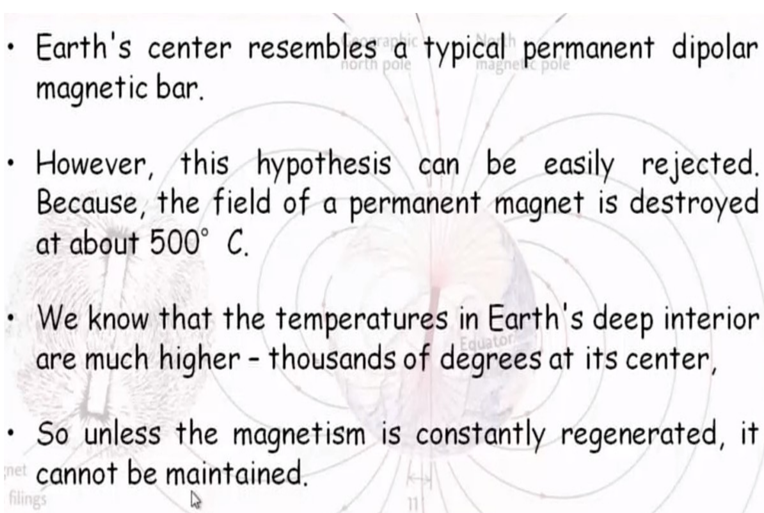

Now further earth's center resembles a typical permanent dipolar magnetic bar or magnetic bar. However, this hypothesis can be easily rejected. Now the formation of the magnet it is not possible because the permanent magnet will be destroyed beyond 500 degree centigrade. So 500 degree centigrade temperature will result in to the destruction of the permanent magnet.

Then what is happening we know that the temperature in earth's deep interior are much higher thousands of degrees at it center. So unless the magnetic or the magnetism it continuously or constantly regenerated it cannot be maintained. So it cannot be maintained without regeneration. Because 500 degree the permanent magnet will be destroyed then why we are still having the magnetic field that exist.

So this is very important that unless there is a regeneration of the magnetic magnet or magnetic field the permanent magnet which we observe or experience the magnetic forces will not exist. So further it was been discussed and the scientist suggested the theory that heat flowing out of earth core now we are talking about the earth core.

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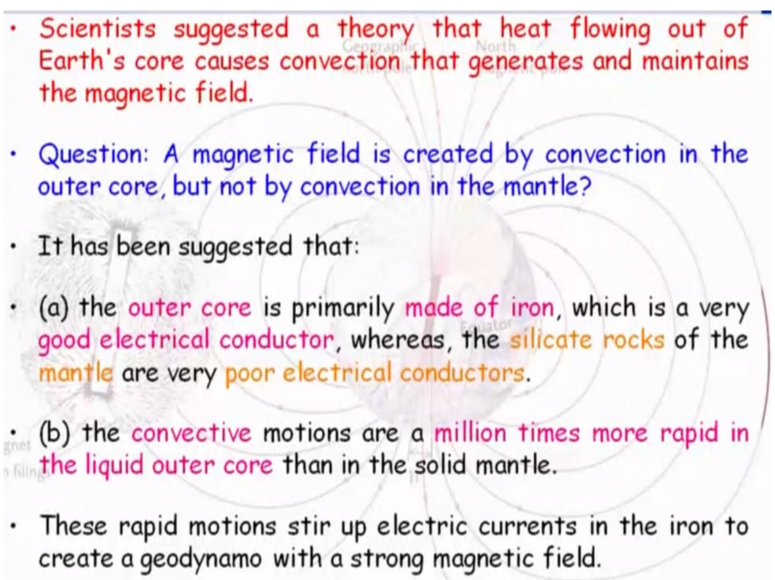

So the heat flowing out of the earth core causes convection that generates and maintain the magnetic field. Now this is very important. But the question again is the magnetic field is created by convention in the outer core but not by convention in the mantle? It has been suggested that the outer core is primarily made up of iron. Now if you remember the composition of the earth so the interior what we have first on the top we have the crust which is comprise of silica magnesia and aluminum magnesium rocks.

(()) (27:26) so we have continental crust we have oceanic crust then we come down to the these asthenosphere which is partially molten and then lithosphere and so on. So the mantle is again not composed of fully iron. But as you move deeper into the interior of the core mostly the interior of the core that is the interior of earth and the inner core and the outer core is comprised of nickel and iron whereas the inner core is maximum you will see the iron.

Because the heavier materials sink down. Now this is the one of the reasons that we are talking about that heat which is been generated or available in the interior of earth because the heat increases and pressure increases as you move from the earth surface towards the interior of earth. And it goes more than 6000 degree centigrade. So the heat which is more in the region of the outer core is responsible for the development of the convention-convection currents very much similar to what you see in asthenosphere.

But in asthenosphere the convection current is slow as compared to what we see or experience in the outer core. So the outer core primarily it is comprised or made up of iron which is very good electric conductor electrical conductor. Whereas the silicate rock of the mantle because the mantle you have silicate rocks as we were talking about the if you take it into consideration the composition of the earth's interior. And this silicate rocks in mantle are poor electrical conductors.

So the convection or convective motion are a million times more rapid in the liquid outer core than in solid mantle. This rapid motion stirs up electric currents in the iron to create a geo dynamo with a strong magnetic field. And this is one of the reason why we see the generation of magnetic field in this region.

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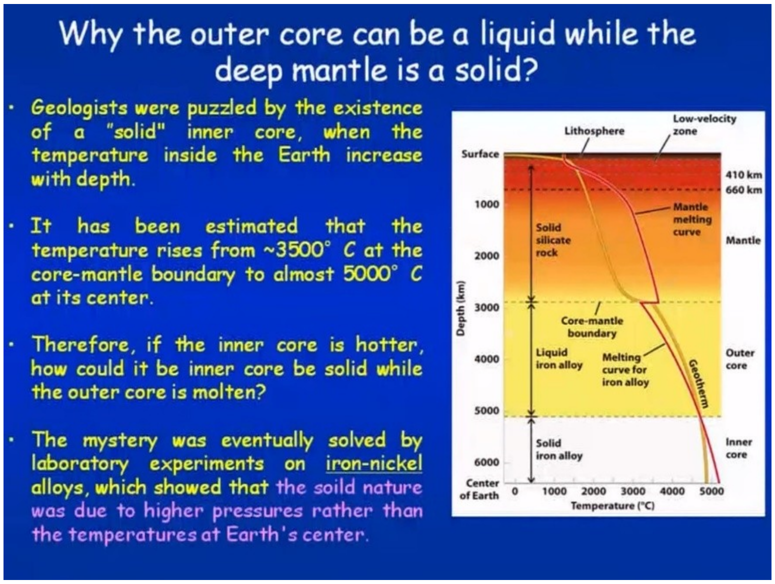

So this was the part of the geo dynamo so why the outer core can be a liquid while the deep mantle is solid? The reason is that the geologist were puzzled by existence of the solid inner core when the temperature inside the earth increases with depth. So inner core is solid where is the outer core is liquid. So it has been estimated that the temperature rises from 3500 degree centigrade at the core mantle boundary to almost 5000 degree centigrade in the center and more. So it goes more than 5000 degree centigrade after the inner core.

Therefore, if the inner core is hotter, how could it be the inner core be solid while the outer core is molten? This is an question so the reason is the mystery was eventually solved by laboratory experiments on iron nickel alloy which shows that the solid nature was due to higher pressure rather than the temperatures of the earth’s center. So this was the reason why you have the inner core as solid because of the higher pressure and not because of the temperature where is the outer core is liquid.

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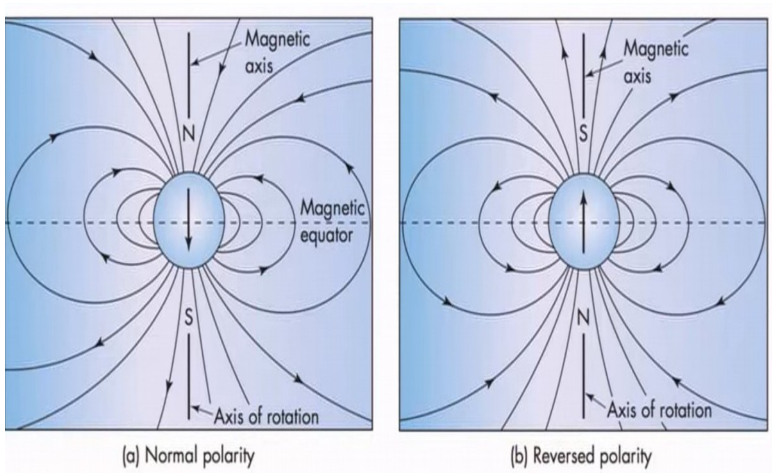

FIGURE 2.12 Magnetic reversal Idealized diagram showing the magnetic field of Earth under (a) normal polarity and (b) reversed polarity. *(From Kennett, J. 1982.* Marine Geology. *Englewood Cliffs, NJ: Prentice Hall)*

(refer time: 32:06) And further as we have discussed that the magnetic polarity never remains the same as we what we see now is north south but at some point of time the polarity will be reversed and this was observed in the area of the spreading centers will be have negative positive anomalies which is been shown by the in the next slide which will be showing.

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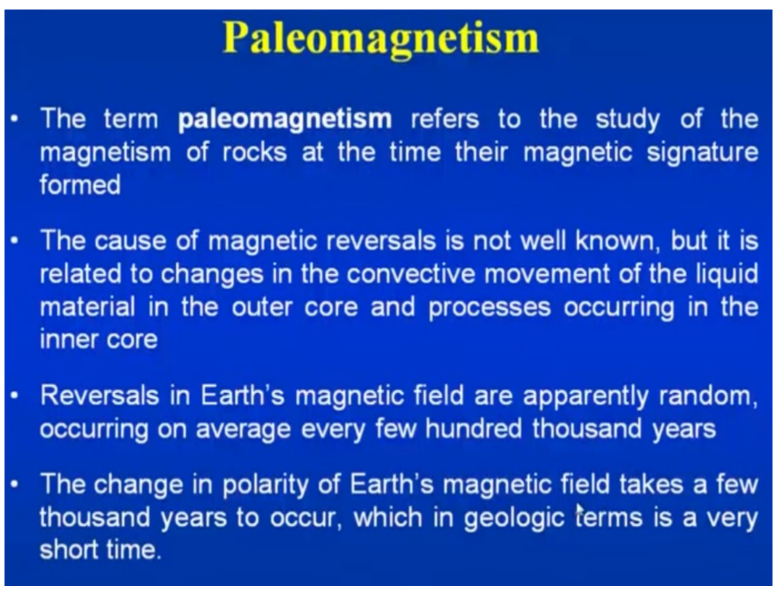

So the term paleomagnetism so paleomagnetism mainly is the study where the magnetic field are being studied and the rocks which are having the different magnetic signature are when reported. So the term paleomagnetism refer to the study of magnetism of the rocks at the time their magnetic signature are as formed. The causes of the magnetic reversals is not fully known but it is related to the change in the convection movement of the liquid material in the outer core and the processes occurring in the inner core.

So in short this is another important point that the in the various disturbance in the convection movements then the polarity may change. So the convection movement in the outer core can result into the magnetic reversal. So the reversal in the earth's magnetic field are apparently random. This again it is not known why but on average every few thousand years it changes. The change in the polarity of earth's magnetic field takes a few thousand years to occur which a geological term is very short time.

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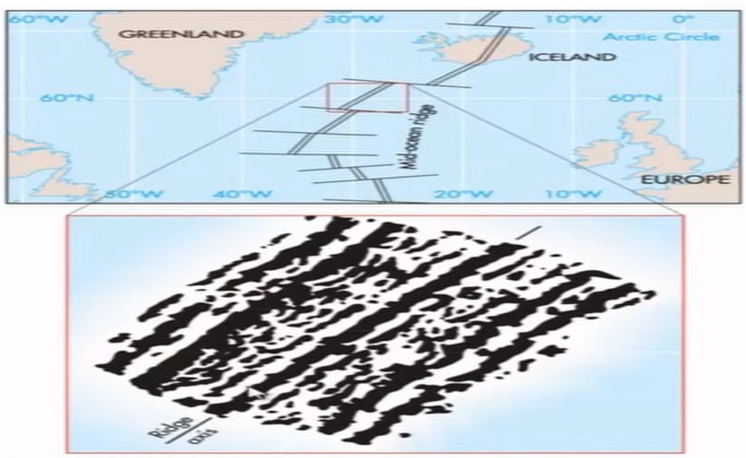

FIGURE 2.13 Magnetic anomalies on the seafloor Map showing a magnetic survey southwest of Iceland along the Mid-Atlantic Ridge. Positive magnetic anomalies are black (normal) and negative magnetic anomalies are white (reversed). Note that the pattern is symmetrical on the two sides of the mid-oceanic ridge. *(From Heirtzler, J. R., Le Pichon, X., and Baron, J. G. 1966. Magnetic anomalies over the Reykjanes Ridge.* Deep-Sea Research *13:427–443)*

So this is been shown here in the mid oceanic ridges where you have the different polarity where the black one is the normal polarity that is the north south what we see now and the negative one where the north pole becomes the south and the south pole becomes take these taken up by the north. So I will stop here and we will continue in the next section. Thank you so much.