Geotechnical Earthquake Engineering

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Module - 3

Lecture - 7

Engineering Seismology (Contd…)

Let us start our today's lecture on Geotechnical Earthquake Engineering. So, in this course geotechnical earthquake engineering, we were discussing on module 3 that is engineering seismology.

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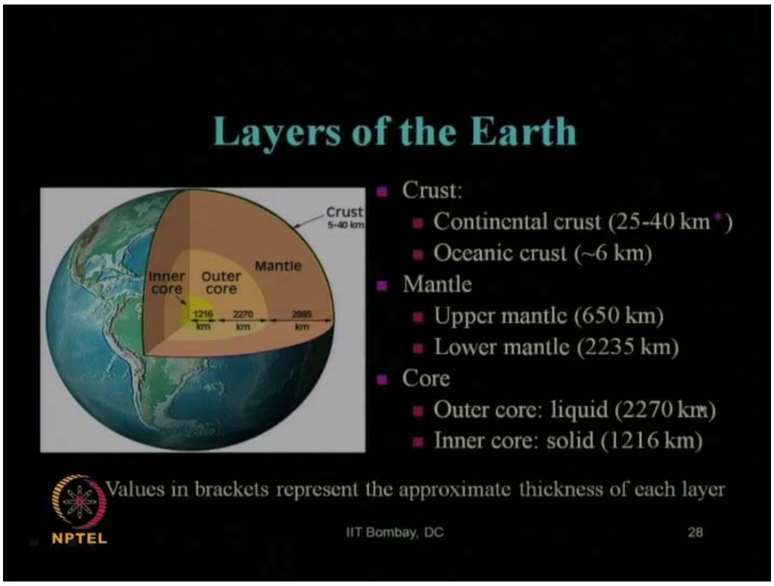

And within module 3, we started discussing on the sub topic on plate tectonics in the previous lecture, a very quick recap what we have learnt in the previous lecture like layers of earth, which is basically sub divided into 3 major zones crust mantle and core with their individual typical thickness, and we have seen the outer core is fully fluidised state and inner core is fully solid state. Also we have learnt that from our experience the majority of the earthquake it occurs within the depth of up to the upper mantle thickness that is about 700 kilometres from the ground surface, that is the crustal thickness plus upper mantle thickness, and the shallow earthquakes occur mostly within the crustal plate.

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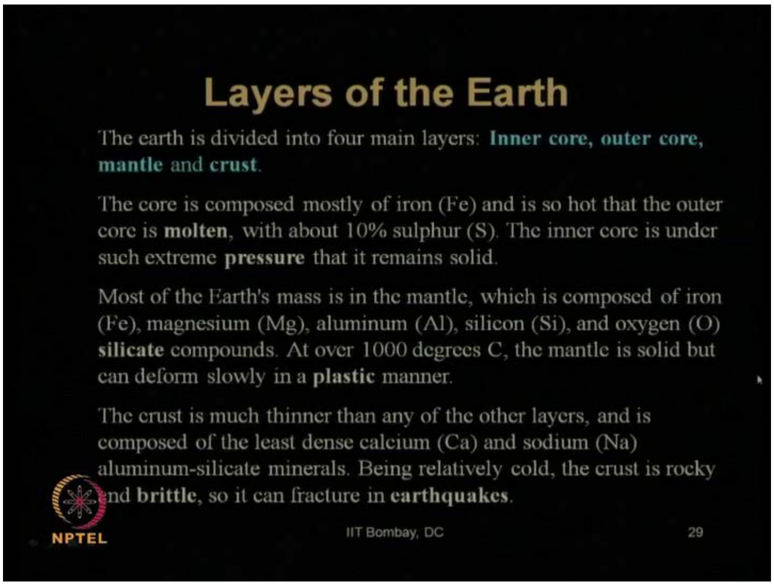

We have also learnt that is once we divide this earth’s interior in to four major area or regions or layers like inner core; which is solid, outer core which is fluid and mantle and crust region. We have seen, what is their basic composition of materials and minerals etcetera, and we found that among these layers the coldest one is the crust or the outer layer and it is the thinnest layer. So, crust is a rocky and brittle type material. So, it can break very easily, that creates the fracture through which we can face this earthquake in from the earth’s interior through the release of the energy.

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Now, let us see a theory which is called continental drift; what that theory means the theory that continents, and the plates of the earth that is at various parts of the earth's crust they are composed a various plates. So, these move on the surface of the earth that is nothing but continental theory or continental drift theory one they move with respect to each other which was proposed by Alfred Wegener in 1915. So, he is the scientist Alfred Wegener, who first proposed this continental drift theory about the movement of these crustal plates.

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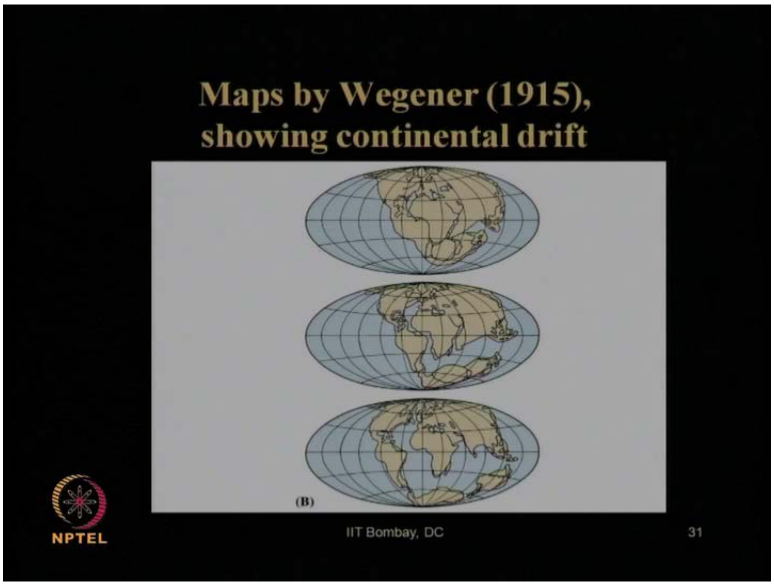

And this is the map proposed by Wegener in 1915, showing the continental drift; that means, initially Wegener said all the continents or the all the plates composed of that continents were together, and once with time the earth spins they started to move apart and of today's continental plates, whatever we see that has been created through several years by the process of that revolution of that earth about its own axis and also around that solar system.

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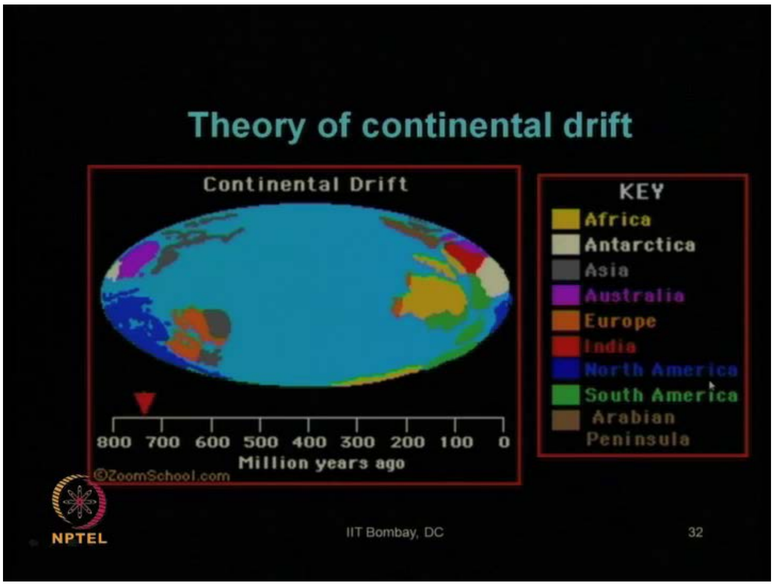

See, if you look at this video small video it clearly shows, that how this theory of continental drift of Wegener came in to picture. So, people say this is 0 means at present, and if we go back million years ago, say about 800 million years ago, you can see when this is at this location all were together, and through the revolution of the earth they slowly, slowly get separated and what we see today's various continents that has been formed like various continents and plates major plates etcetera this things have been formed.

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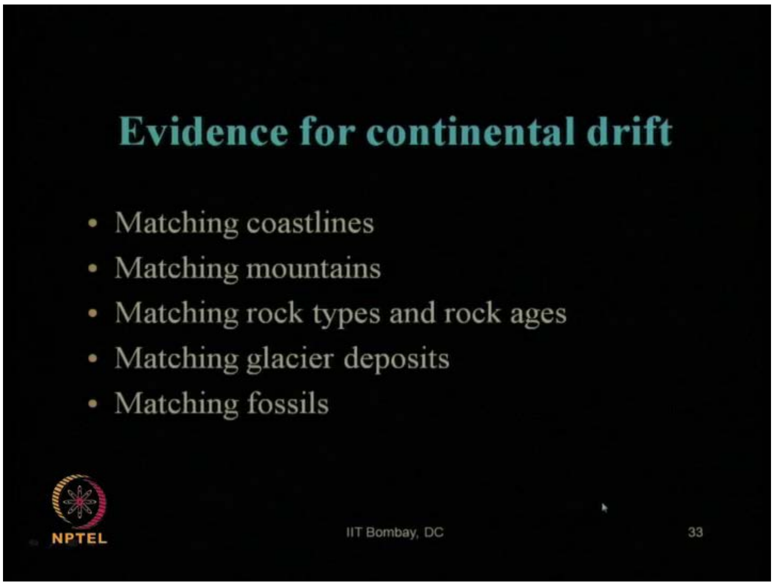

Now, in support of Wegener's continental drift theory, what are the evidences he proposed that which shows that continental drift has occurred or this plates have moved with time, the proof is that they have mentioned the evidence is that, if you match the coastlines of different continents or if you match the mountains of different regions or continents or if you match the rock types available, and the ages of those rocks available at different continents. If you match the glacier deposits and various continents and also, if you match the fossils available at various continents.

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If they match similarly then; obviously, one can say at certain point of time some million years ago they were together and with time they got separated. Let us see some of these pictures. If you look carefully at the eastern part of this south American plate, and the western part of African plate, you will see their coast line matches very well; that means, it automatically says, as if these 2 blocks were together, and which time they got separated by this continental drift theory of Wegener.

So, this is the concept to match the coastline. If the coastlines are matching of 2 continents; obviously, it shows that some point of time, they must remain together, and with time because of movement of the earth, spinning of the earth with time slowly slowly they got drifted, that is continental drift, and got separated to take today's shape of this 2 continents.

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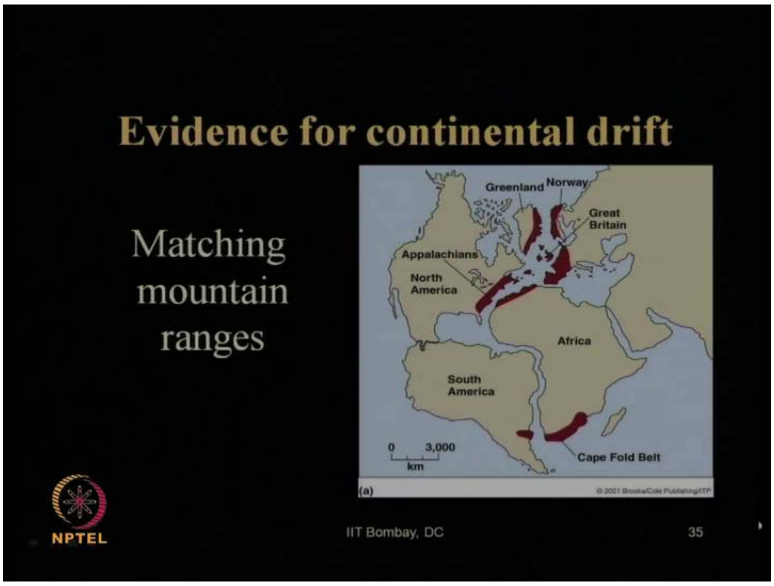

Similarly, the matching; the mountain ranges, if one look at the mountains available, the mountain ranges available; this eastern actually south eastern part of north America, north western part of Africa; this south western part of great Britain and Europe. Then green land this part, Norway this part etcetera, they composed of single mountain ranges. So, if you close and bring those blocks together, they will form a single mountain ranges similarly at this location, also with Africa and south America which automatically shows that probably once upon a time they were together, and with time they got separated out and today's various continents got formed. So, this is another evidence for the continental drift theory of Wegener.

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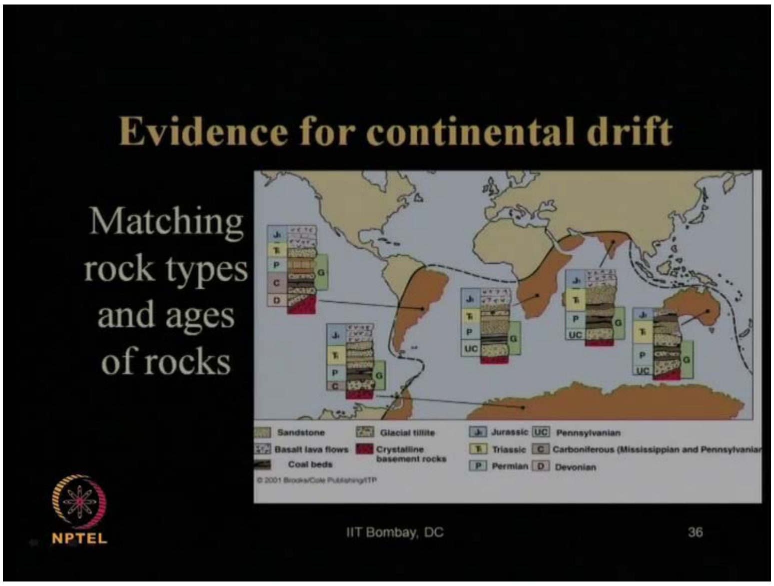

Then matching rock types, and the ages of the rock available at various locations, if you look at various spots like; this is the South American plate; these are the types of rocks and their ages etcetera. If you find out in this region of Africa also in southern part of our India and the Australian plate, all these are having similar type of layering of rocks. Also with their similar age period like Jurassic, Triassic, Permian etcetera, and various layers you can see the Basalt lava flows then sandstone then coal beds etcetera.

So, what it indicates, if all these shaded regions are having similar type of rocks with similar ages of them with the similar form of layering of course It indicates that once upon a time, they were at the together or they were at the same place, then with time they got separated, this is another evidence for the Alfred Wegener's continental drift theory.

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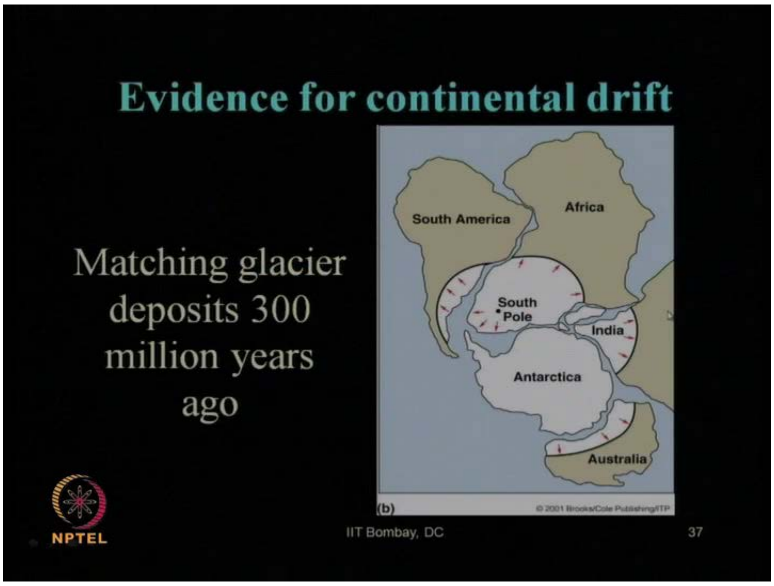

Another evidence is matching the glacier deposits of 300 million's years ago, you will find out that glaciers of this portions, they were together with that Antarctica; that automatically shows that probably, they were together once upon a time, and then got separated with time.

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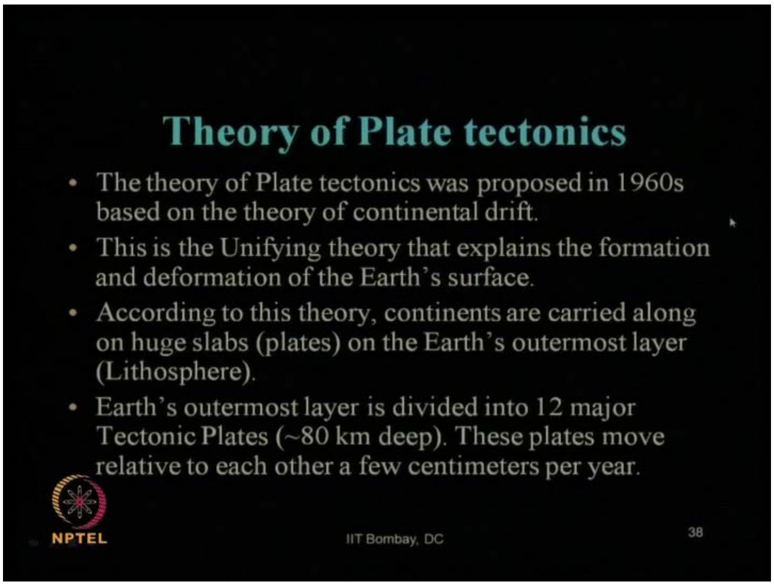

So, now coming to this theory of plate tectonics, the theory of plate tectonics was proposed in 1960s, based on that Alfred Wegener's theory of that continental drift; that is those continental drift must have occurred with time created that plates, and that plate tectonic theory arrived in 1960. So, this is the unifying theory that explains the formation and deformation of earth’s surface. According to this theory, continents are carried along on huge slabs which we called as plates on the earth’s outer most layer or lithosphere; that is the crustal plates or continental plates, an earth’s outer most layer is divided in to 12 major tectonic plates typically about 80 kilometres deep, and these plates move relative to each other by few centimetres per year; that means, even today also this different plates of earth they are moving by few centimetres. And these 12 major tectonic plates are present, which are having a typical depth of about up to 80 kilometres, and this plates can be oceanic plate and continental plates all together.

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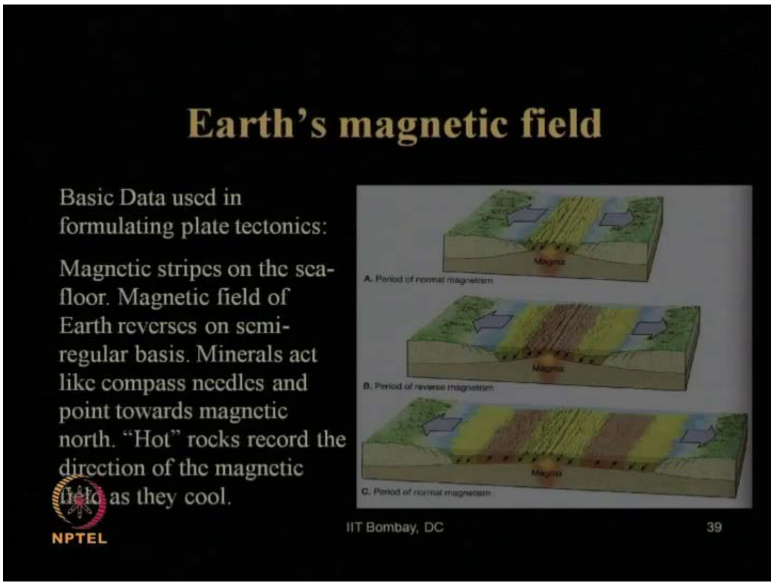

Let us see now the picture of that earth’s magnetic field that is basic data used in formulating the plate tectonics that is how these plate tectonics came in to the picture. It is believed that magnetic strips on the sea floor and magnetic field on earth that reverses on semi regular basis; that is once it is south pole another north pole like that they reverses on regular basis and minerals act like compass needles; that is some minerals gets attached or attracted to this different poles or different sides of the magnetic field, and point towards the magnetic north.

So, hot rocks; that are the rocks which are still at a higher temperature at a larger depth record the direction of that magnetic field as they become cooler, when they come closer to the ground surface. So, if you see over here period of normal magnetism that is when the magma that lava comes out from earth's interior during the cooling process they moves apart in this direction that creates a normal magnetism field and accordingly other minerals etcetera, gets oriented to the magnetic north, and period of reverse magnetism the other case; next case what it happens is magma goes in to the next phase. It comes out another direction, another reverse formation, and period of again comes normal magnetism like this.

So, if you see the colours changes. So, normal magnetism with time it goes to reverse magnetism. Then it goes to again normal magnetism like this the cycle the goes on moving and accordingly the earth's minerals they get oriented and hot rocks also they get the directional field of this earth's magnetic field.

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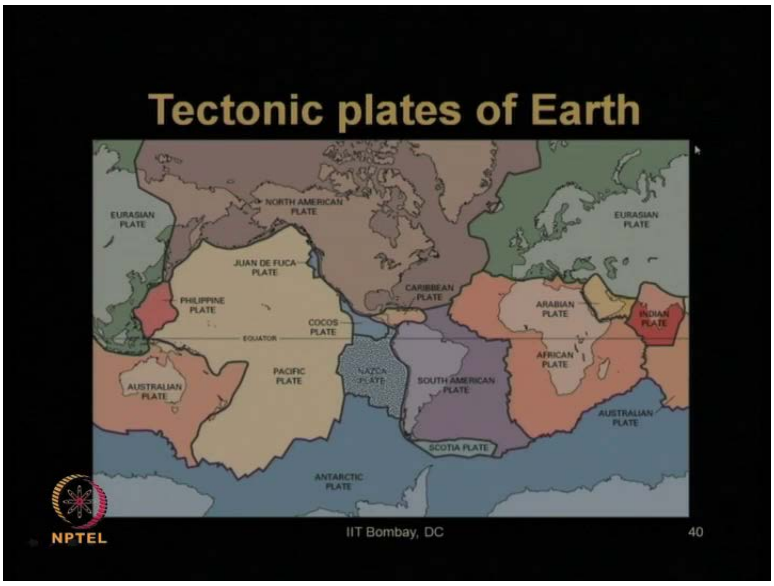

Which is the basic cause of this tectonic plate movement? So, 12 major tectonic plate movements we have mentioned; these are the tectonic plates which earlier also we have seen like Indian plate, Australian plate, Arabian, African, Eurasian, south American, and various others; this is Antarctic plate; there is Pacific plate. So, it includes both continental plate as well as oceanic plate.

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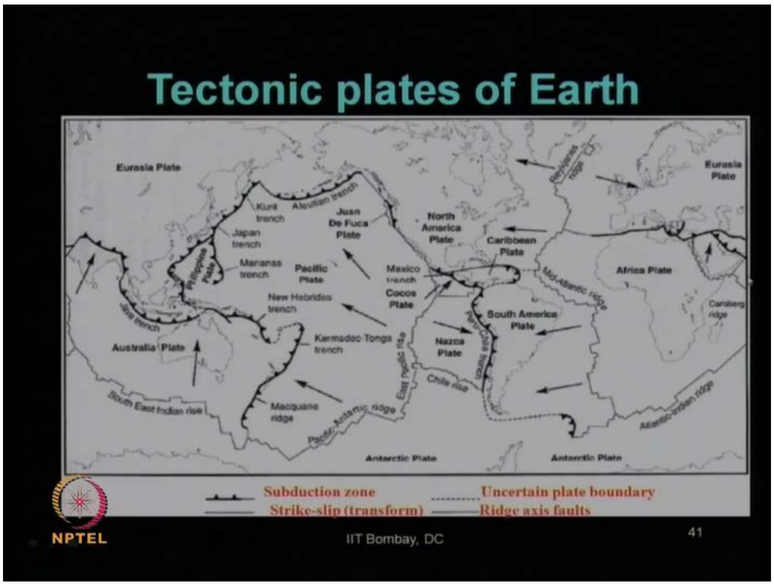

Now, if we look at the history of earthquake. We will see that this tectonic plates of the earth along their boundaries; that is where the 2 plates meet each other along their boundaries. These are the probable locations of more earthquakes why, if you look at here various symbols; this symbol shows subduction zone. So, all these are subduction zone including you can see here the Indian plate and Eurasian plate.

So, Indian plate, if you look at the direction that subducts; that is goes below this Eurasian plate that is the reason why there is a formation of mount Himalaya and it still builds up in the height every year by few centimetres. Similarly, at other locations also you can see various subduction zones and the direction indicates which plates subducts in to the other plate, like this Nazca plate subducts in to the South American plate.

Then there are strike-slip or transform type of movement; this solid lines which gives; we will discuss about what is strike slip movement. When we will discuss about the faults etcetera, uncertain plate boundary this dotted line; that is people are not sure about whether this plate boundary exist are not; this one there also chances are there, and ridge axis faults various ridges. You can see mid Atlantic ridge; this axis faults can create possible plate tectonic movement which in turn will cause the earth quakes.

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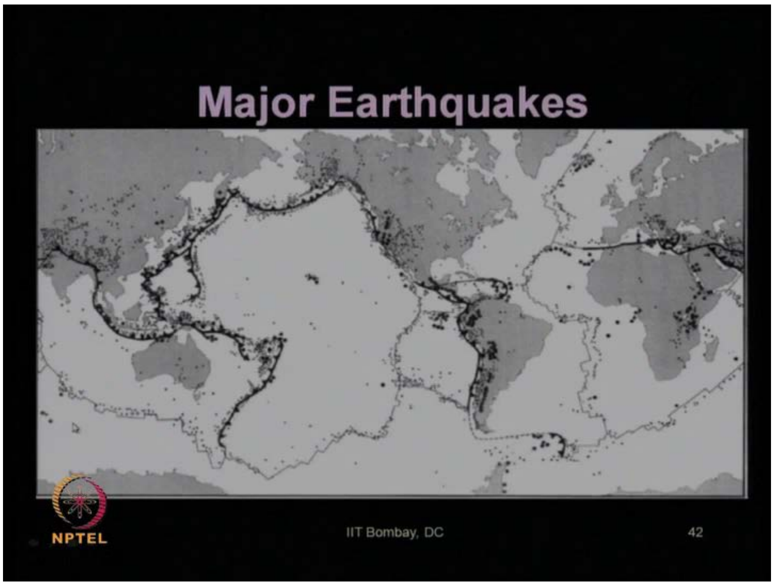

So, if we look at the picture next major historical earthquakes are big earth quakes occurred, if you see all along first of all this subduction zones or the plate boundaries as well as through this ridges and those strictly fault various locations. So, these are the major zones where big earth quakes occurred historically as well as in future also it can occur.

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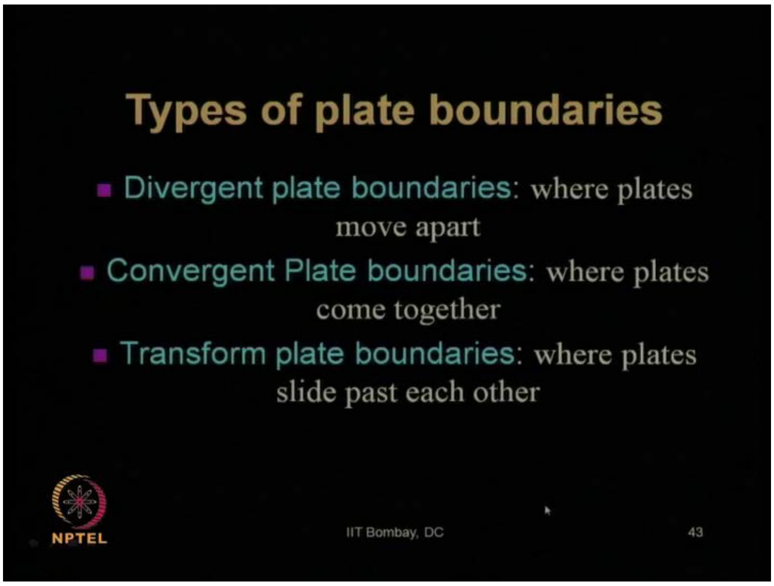

Now, what are the types of plate boundaries like, when we talk about this plate tectonic boundary there are different types of this plate boundary, and depending on their movement etcetera.

So, let us see, what are the major types of that plate boundary? there can be 3 major types or categories of plate boundary; one is called divergent plate boundary. In this divergent plate boundary what happens the plates move apart that is one plate is going away from other; 2 plates are moving away from other. So, that is why it is called divergent plate boundary movement; next one is called convergent plate boundaries that is when 2 plates come together; that means, 2 plates they are coming together or converging to each other, that is convergent plate boundaries and the third one is called transform plate boundaries.

In this case, where plates slide past each other; that is when these 2 plates they slide with respect to each other side by side like this that is called transform plate boundary. So, these are the 3 major plate boundary movements.

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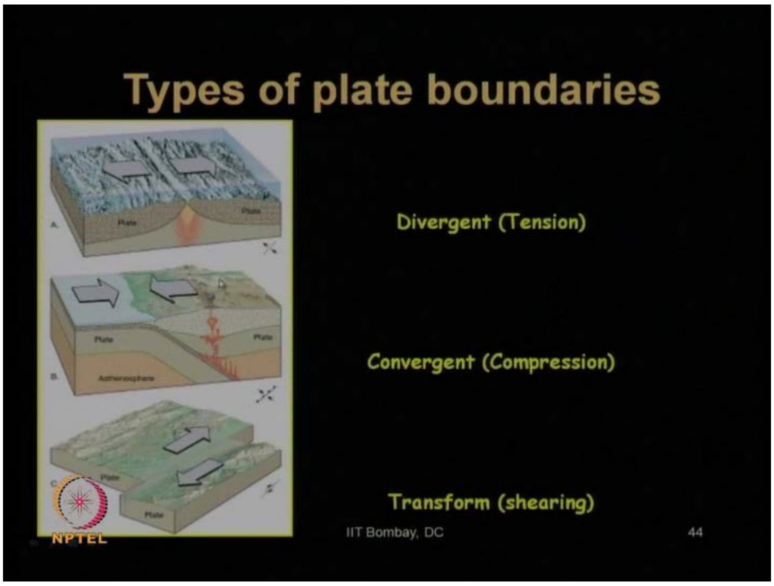

So, you can see in this picture; this 3 major types of plate boundary movement; the first one is divergent 2 plates are moving away from each other, and in that intersection; this lava or magma is coming out and; obviously, these 2 plates will be in tension as you can see from the figure when the divergent plate boundary movement is occurring.

When it is 2 plates are converging to each other. It is convergent plate boundary movement in that case; there is a chance that one plate goes below the other and one over tops the other. So, that convergent plate boundary movement will be subjected to compressional load or compressional force as you can easily see from this force direction, and transform or shearing or sliding with respect to each other 2 plates. The forces acting in this direction, you can see these different 3 types of plate boundary, and the different forces responsible for that tensile force compressive force, and shearing force.

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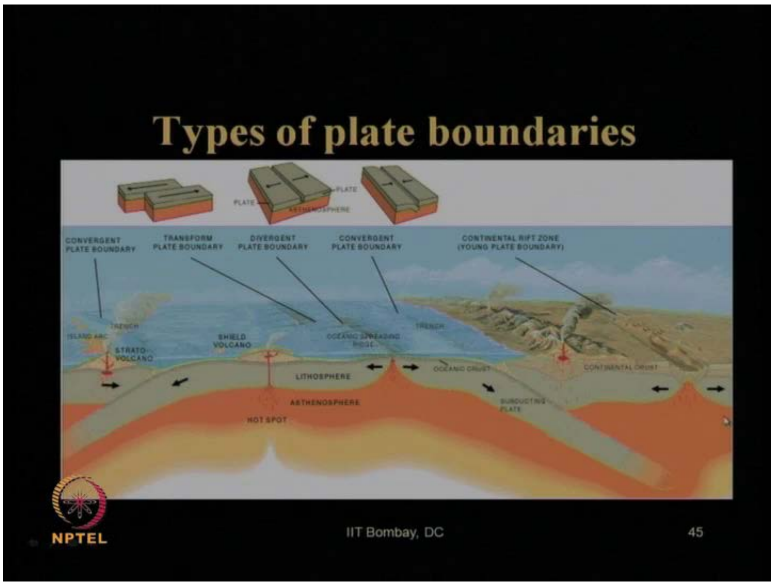

Now, these types of plate boundaries at different locations, you can see over here. This is convergent plate boundary as we have seen 2 plates are converging to each other, and one has to of course; go below the other when they are converging; this is divergent plate boundary, and this is the transform plate boundary.

At different locations of earth’s crust it can occur; that means, at one part suppose of the earth’s crust whether it is oceanic crust or continental crust, and say it is occurring the convergent plate boundary movement. Another part will have the divergent plate boundary movement, because which are quite obvious, if one side 2 plates is moving with respect to each other converging. So, then this plate has; obviously, moved with respect to its next plate in a divergent manner.

So, it goes in cycles like one part of the crustal plate will be moved convergently. Similarly the next phase or next part will move divergently, and in between the process there can be a shearing also which can be a transform movement of the boundary. So, that is why in this picture as you have seen that can be divergent plate boundary, convergent plate boundary and transform plate boundary, and if you look here this divergent plate boundary will create this lava eruption or volcanic eruption even the convergent plate boundary also can create volcanic eruption here.

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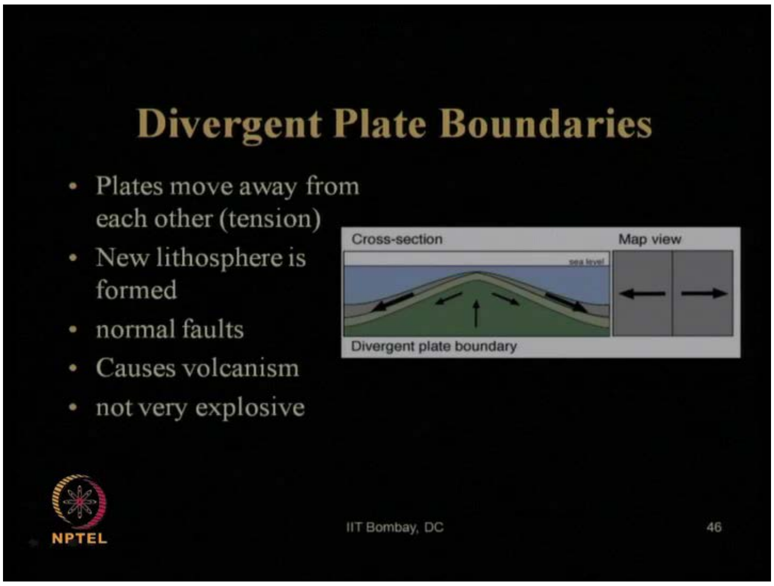

So, the divergent plate boundary as we have seen just now 2 plates; this is the map view or top view or plan view moves away from each other creating this tensile force to each plate. And if you see the cross section of divergent plate boundary, these 2 plates are moving away from each other, in that process what happens; new lithosphere is formed because earth's interior gets exposed so; obviously, it creates a new lithosphere, and it forms the normal faults; that is the fault which is subjected to this kind of divergent plate boundary and tensile force in this manner the fault which gets created is called as normal fault. So, normal faults are subjected to tensile force, and it cause volcanism because you can see when some earth's interior is gets opened up, there is a high chance that the molten or the high temperature earth's interior can come out in the form of a lava or volcano.

So, that is why it causes volcanic eruption, but it is not very explosive, that is it does not create huge explosion sound, why because in this case 2 plates are not colliding with respect to each other, they are moving away from each other, that is the reason it does not create much of a collision sound between the 2 plates. When they are actually strike each other instead of that they are moving away from each other so; obviously, they are not creating any explosive sound or etcetera in this divergent plate boundary movement.

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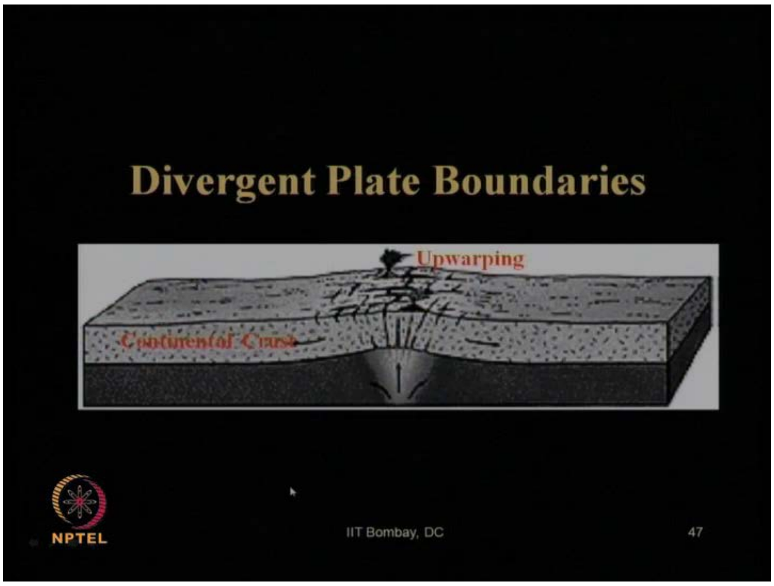

If we see this picture once again, so 2 plates as this arrow shows go out; this lava comes out; this is continental crust divergent plate movement; up wrapping here occurs.

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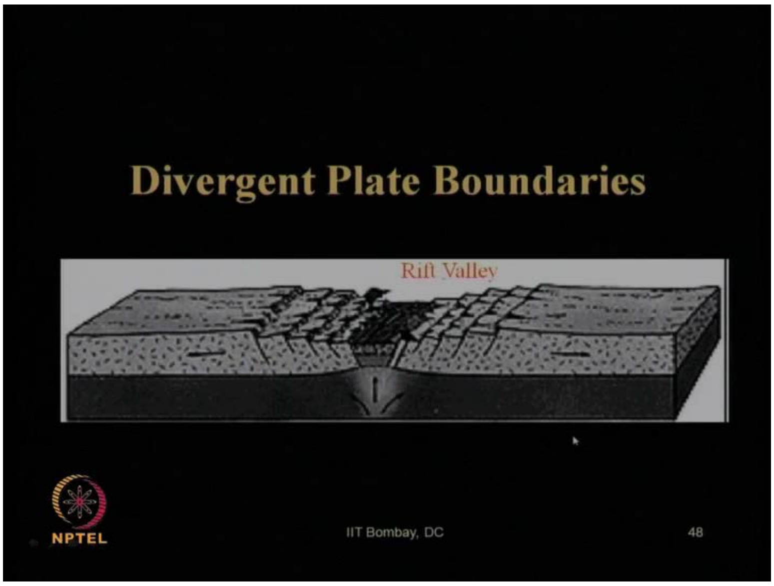

And another one it creates a rift valley finally, once this 2 plates move away. So, it creates a valley here.

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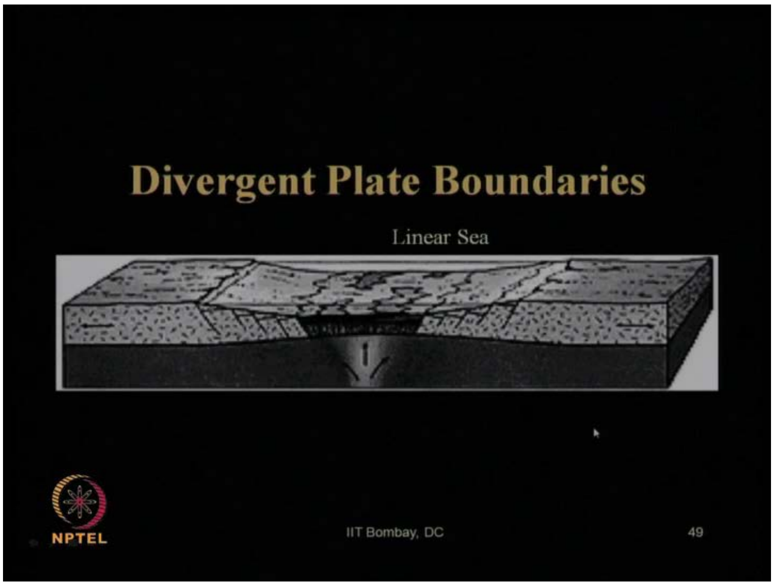

And sometimes that valley in future if it filled up with water etcetera, it can form a linear sea. So, that divergent plate movement can create a water body or sea in this process.

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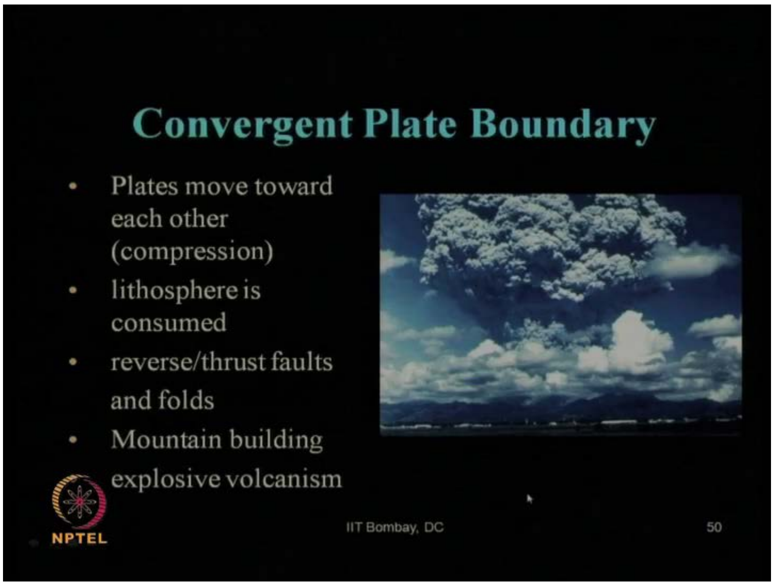

Now, convergent plate boundary; that is the other one plate movement, in this case plates move toward each other, we have already seen they are subjected to compressional load. So, lithosphere is consumed in divergent plate boundary new lithosphere has been formed opened up. In this case; whatever lithosphere or ground surface was existing that get consumed means some part of it get goes below to the other plate so; obviously, whatever was existing earlier they go inside now, they are no longer remains as a open ground surface they goes below. So, that is why it is said in this process lithosphere is consumed, and this case the faults which are created those are known as reverse fault or thrust fault and folds.

So, this reverse fault is nothing but subjected to compressional load and created in the process of convergent plate boundary or in the process of convergent plate boundary what happens; mountain builds up because when 2 plates slides and converge with respect to each other, and one goes below another goes up they are creating a pressure between them, and automatically the inside, whatever is there that tries to lifts up that creates the formation of mountains.

So, that is why mountain building occurs in this convergent plate boundary and it creates explosive volcanism; that is in this process also the volcanoes can come out, but with a big sound that is when this 2 plates are converging or colliding with respect to each other there will be huge sound because in this case plates are coming or hitting each other, where as in the previous case divergent plate boundary they were going away from each other. So, there was no explosion or there was no large sound of explosion, but in this case there is a large explosive sound with volcanism.

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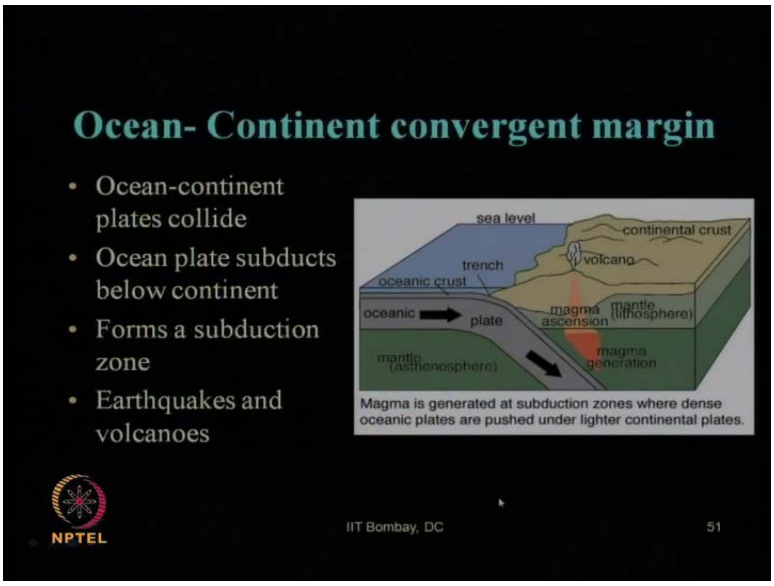

Now, let us see few examples like ocean continent convergent margin; that is suppose when there is an oceanic plate converges with a continental plate then what happens. So, ocean continent plates collide with respect to each other, look at here; this is the oceanic crust and this is the continental crust, these 2 plates converging with respect to each other so; obviously, as I said the weaker one has to go below the other one.

So, in this process; which one will be the weaker plate typically we have seen from the earth’s interior data, generally the oceanic plates are weaker plates, because of their thickness compare to typical thickness of a continental plates. So, ocean plates typically sub ducts below the continental plates and that creates a subduction zone, and that creates earth quake and volcanoes. So, if we look at this picture; this is called trench; this oceanic plate moves down below this continental crust or continental plate. So, that gets subducted here, and in that process the volcano gets created, and when these 2 plates hits each other; obviously, an earthquake or tremors is occurring.

So, magma is generated at the subduction zone, where dense oceanic plates are pushed under lighter continental plates because typically oceanic crust are denser material, and continental crust are lighter material so; obviously, the lighter part will come up, and the denser part will go in. So, that is why this magma or the volcanic eruption will take place. In this process along with the earthquake and you can see another thing as 2 plates collide in this close to the boundary there is an uplift of this plate, which is nothing but formation of that mountains because of hitting of this 2 plates this portion goes up with the formation of this volcanic eruption.

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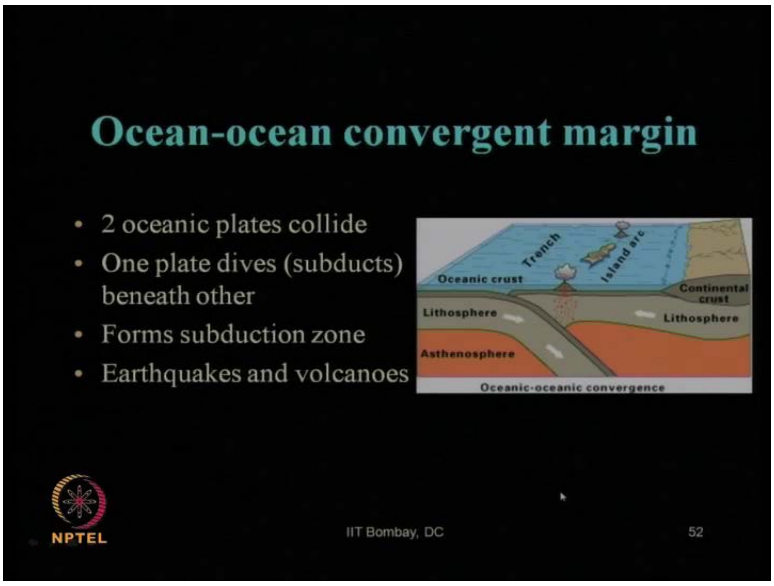

Now, when ocean plates converge with respect to each other; that is 2 oceanic plates when they converge. So, 2 oceanic plates collides with respect to each other oceanic crust, oceanic crust, one plate dives or sub ducts beneath the other; one of them has to go below another has to go up because they are colliding so; obviously, one has to gets subducted that forms a subduction zone. And here also earthquake and volcano gets created. So, that is why volcanic eruption can take place inside an ocean also. So, that is why you can see over here inside the ocean also volcanic eruption takes place, and at this location earthquake can occur.

So, once this earthquake occurs because of this 2 oceanic plate movement; obviously, it will be an earthquake focus within the ocean, and that may create tsunami or may not create depending on the whether there is any vertical movement of these 2 plates or not.

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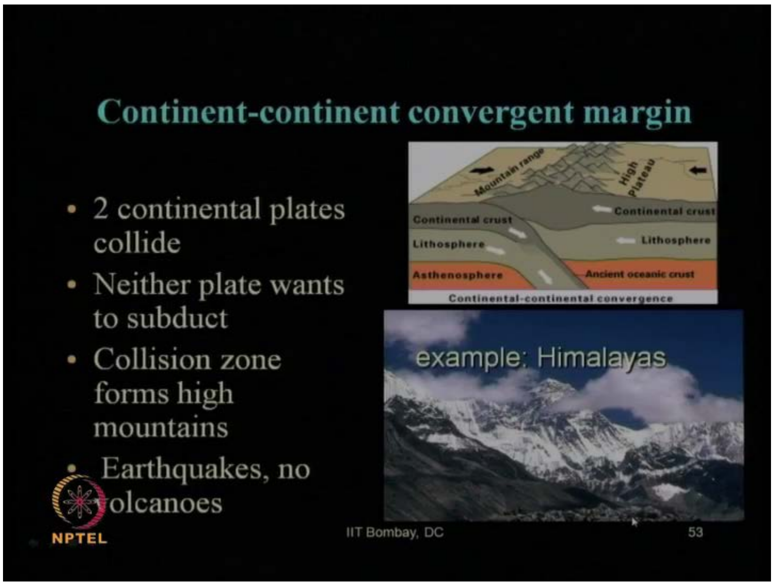

Whereas, another type of convergent plate movement is continent to continent plate convergent movement. So, when 2 continental plates collide with respect to each other, then we say continent to continent convergent movement like 2 continental crust hitting each other or moving towards each other or converging, then in this case what happens; neither the plates want to subduct, but finally one has to get subducted whichever is the higher density or weaker one.

So, collision zone forms and high mountains are getting formed. So, 2 plates are colliding high mountains are getting formed in this case whereas, in the first case we have seen, when there was ocean continent convergent movement there also some mountains get formed, but that is a shallow mountain. And this continent-continent plate movement it creates a high mountain because 2 plates of similar material property etcetera has getting collided whereas, ocean plate; ocean plate movement in the ocean they create only the volcano. So, those are different types of things getting originated from this plate boundary movement.

So, here earthquake occurs, but mostly no volcano's that is for continent-continent movement here mostly no volcanic eruption takes place, but earthquake of course, it occurs due to hitting of this 2 continental crust, a good example of that is formation of Himalayas. So, which continental crust collides in the formation of Himalaya; the Indian plate and the Eurasian plate? So, which plate gets sub ducted; Indian plate goes in it gets subducted over the Eurasian plate, and Himalayas is getting formed, and still today it is rising.

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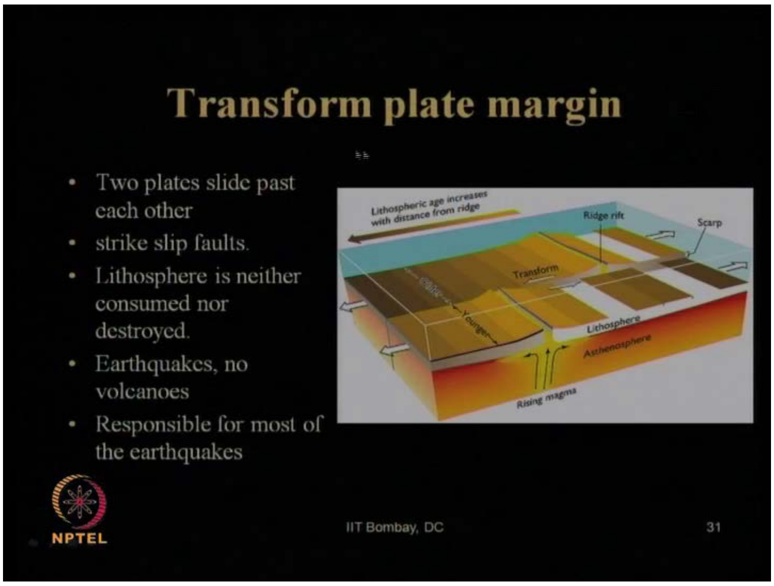

So, after divergent, and convergent plate boundary movement, the third type of plate boundary movement is transform plate margin, as we can see in this slide; this picture shows, how the transform plate margin or transform type of plate boundary movement occurs. So, in this case typically 2 plates slide past each other, and typically one of the plates will be younger one as per the geologic age, and another one will be the older one.

And this type of transform plate margin creates or develops through this strike slip faults. So, the fault which gets formed or visible in the form of this transform plate margin is nothing but called strike slip faults. And in this case of transform plate margin, where 2 plates slide past each other, lithosphere is neither consumed nor destroyed; that means, both the layers their top surface portion remains intact because unlike in the convergent or divergent movement in the convergent movement; what we have seen plate boundary movement one of the plate goes in over the other plate.

So, one subducts automatically as we have seen one lithosphere gets consumed that is what we mentioned whereas, in the divergent plate boundary what we have seen by the movement of the 2 plates a new lithosphere is formed; new another ground surface is getting formed whereas, in this case of transform plate movement, where 2 plates slide past each other like this neither new lithosphere is forming nor any lithosphere is getting consumed. So, that is what it is mentioned over here neither it is consumed nor destroyed or nor formed.

And in this case, mostly earthquake occurs, and rarely any volcanic eruption will occur. Though in this picture, you can see there is some rising of the magma which may take place in the younger portion of the plate rather than the older one, but if we talk about the plate boundary movement. There will be hardly any case of volcanic eruption, there will be only the earthquake.

If we talk about the movement of the 2 plates that boundary itself, and it is responsible for most of the earth quakes in the world; that means, both convergent, and divergent type of movements are also responsible. But more common type of earth quakes in the world are occurring due to the transform plate type movement, like earlier as we have discussed for the creation of the tsunami. We need a certain vertical movement between the 2 plates, which is possible in the divergent or the convergent type of plate boundary movement, but not in this transform plate type of boundary movement.

So, in this transform plate, if this type of earthquake occurs inside a sea; this will not create any tsunami because there is no vertical movement as such between the 2 plates. There is only this lateral shift or lateral slide or lateral displacement occurs between the 2 plates fine.

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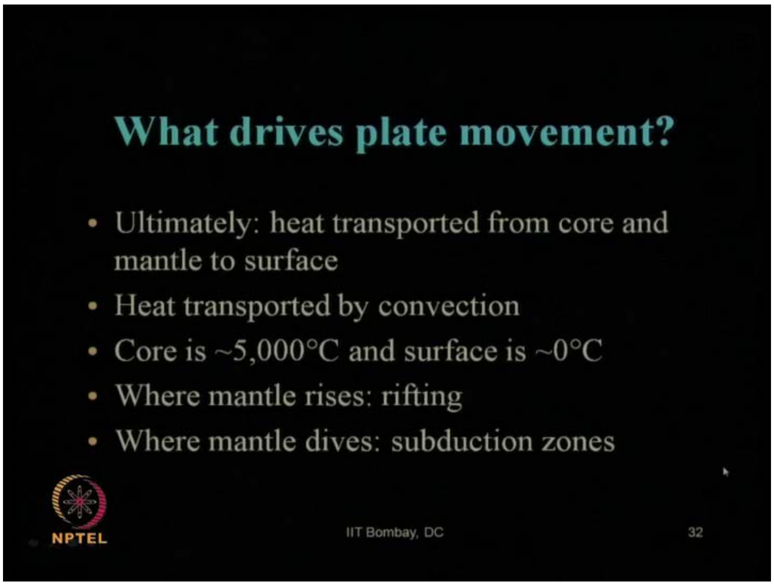

Now, what drives this plate movement because we should know; why these plates should move with respect to each other. The reasons are you can see over here the points. Ultimately the heat which is getting transported from the core of the earth through the mantle of the earth to the ground surface, because we have already mentioned the earth's interior is having very high temperature. And what are the temperature variations you can see in this third point, typically the temperature of earth's core is about 5000 degree centigrade, and the ground surface is close to about 0 degrees centigrade.

So, you can see the wide range of variation between the earth's interior to the ground surface, and that temperature difference, huge temperature difference creates this heat energy to gets transported from core to the surface through the intermediate layer of mantle by the process of convection. So, heat convection theory is valid in this case what we learnt in our physics course in high school physics that heat convection theory is responsible for transporting the heat from the earth's interior core to the surface and in this case, where the mantle rises that is called rifting, and where the mantle dives that is goes inside that creates the subduction zone. So, these 2, we have actually seen in the case of this subduction zone is responsible or getting formed in case of convergent type of plate movement whereas, this rifting occurs in the process of divergent plate type of movement.

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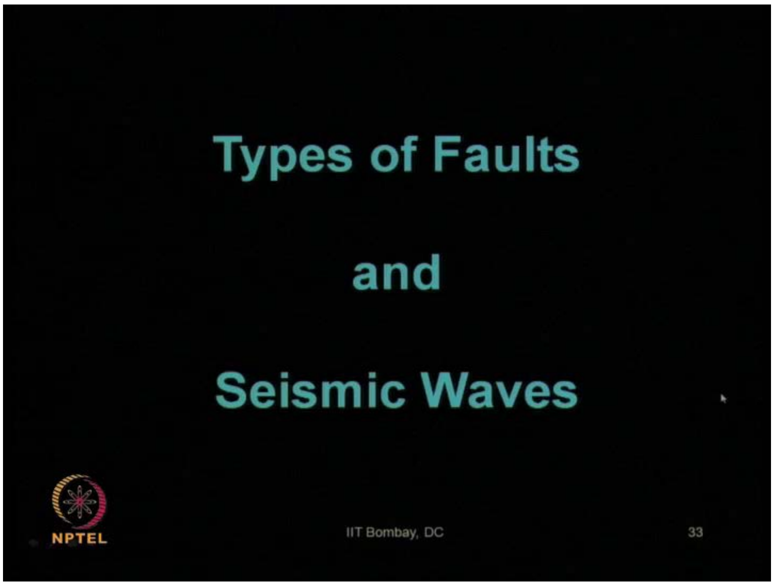

Now, let us come to our next subtopic within this same module on seismology. The next subtopic is types of faults and seismic waves. So, let us see; what are the various types of faults during an earthquake. We can classify, and after that we will see; what are the various types of seismic waves which are getting generated during an earth quake event.

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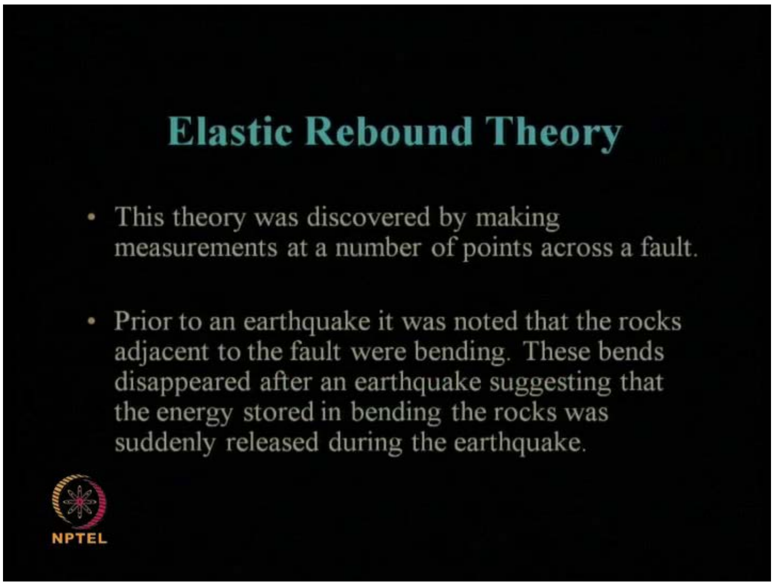

Now, before we talk about the types of faults, we should know one theory which is known as elastic rebound theory what this is. So, this theory was discovered by making measurements at a number points across a fault that is whenever there is a fault which is nothing but weaker section in the earth's crust along that fault if we measure at number of points how the movement or bending or stresses generated etcetera is taking place across those points that we can establish through a theory which is known as elastic rebound theory.

So, prior to an earthquake, it was noted that the rocks adjacent to the fault were bending these bends disappeared after an earthquake, suggesting that the energy stored in the bending of the rocks was suddenly released during the earthquake. Let us see this statement through the pictures. So, our theory will be clearly understandable.

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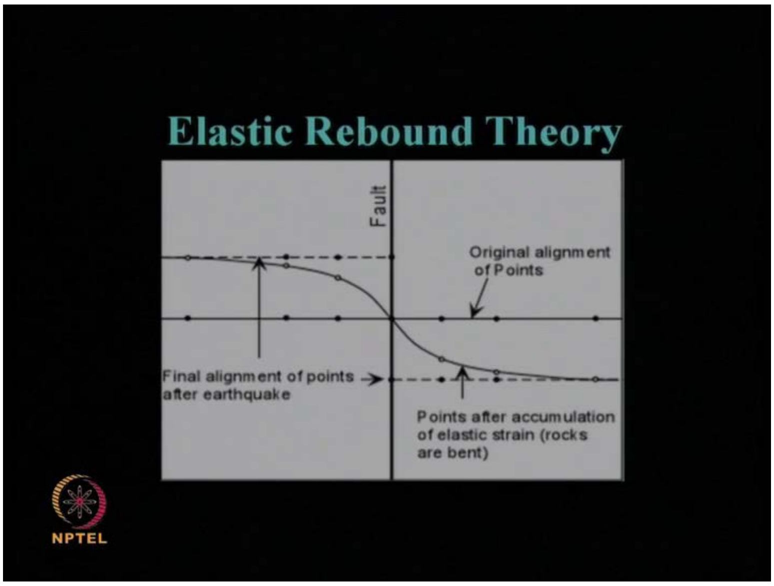

So, this is the pictorial representation of this elastic rebound theory. Suppose, if we have a fault over here like this, and the original alignment of the points across the fault is like this, where these are the dotted marks initially before there is a movement between the 2 plates. So, this is one plate; this is another plate, which was initially together, but there was a weaker zone between the 2 plates, which is known as fault like this.

Now, what happens, there is points after accumulation of elastic strain that is rocks are trying to bend, and that bending occurs as we have mentioned; what drives the plate movements. So, because of those reasons etcetera this rock gets accumulated with elastic strain. So, this bending occurs to this original line. So, this original straight line through this weakness within that rock will try to get bend like this, and once it gets bend then that sudden release of the energy will occur during the process of the earthquake, and when that energy gets released; what happens finally, this line which intermediately got bend like this will take the final shape, which is shown here by this dotted lines.

So, this is the final alignment of the points after the earthquake; that means, when the energy gets released these initial point takes the position of final points on this dotted line over here. So, that automatically shows that these 2 rocks now have moved over this fault or through this fault by an amount of this. So, if we talk about the various steps of this elastic rebound theory of earthquake.

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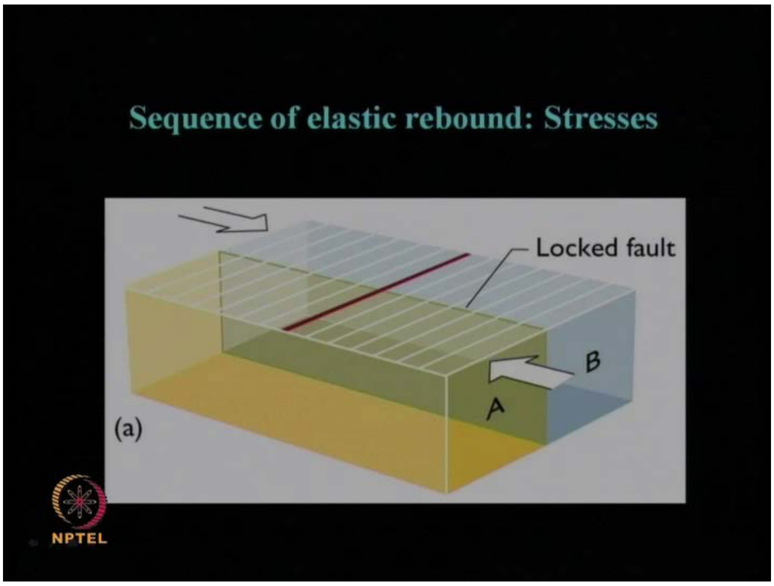

So, these are the various sequences of elastic rebound. So, the first sequence in that list is development of the stresses within the rock, and that development of stresses occurs because of we have seen heat convection temperature difference etcetera from core to the ground surface. So, initially this is the single rock block with some weakness within that, which is mentioned here as locked fault locked means this fault was not initially visible.

So, nothing no movement, no facture nothing occurred at this fault. So, that is why, it is a locked fault, and let us see, how we monitor the movement of the points over this red line. Now, let us take the example of only the transform type of plate boundary movement. It can occur for different types of plate boundary movement of course, but here we are showing for transform type. So, this 2 blocks A and B which were initially together will move or slide past each other over this weakness region which is nothing but this fault. So, the stresses get developed within this rock, which is trying to get release through this weaker zone within that rock.

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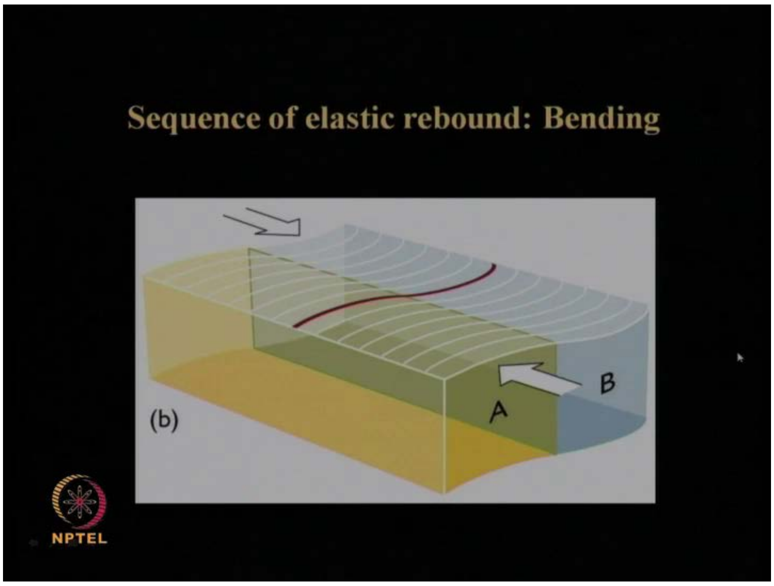

So, the next step or the next sequence in that elastic rebound theory is bending. So, once this rock is subjected to stresses; variable stresses it goes through a process of bending because 2 different stresses or forces are getting generated on this; one from this side another from this side, and because of those 2 stresses it gets bending. So, it gets the shape bending shape like this and you can observe the movement of this point or the points on this line which we are monitoring through this process.

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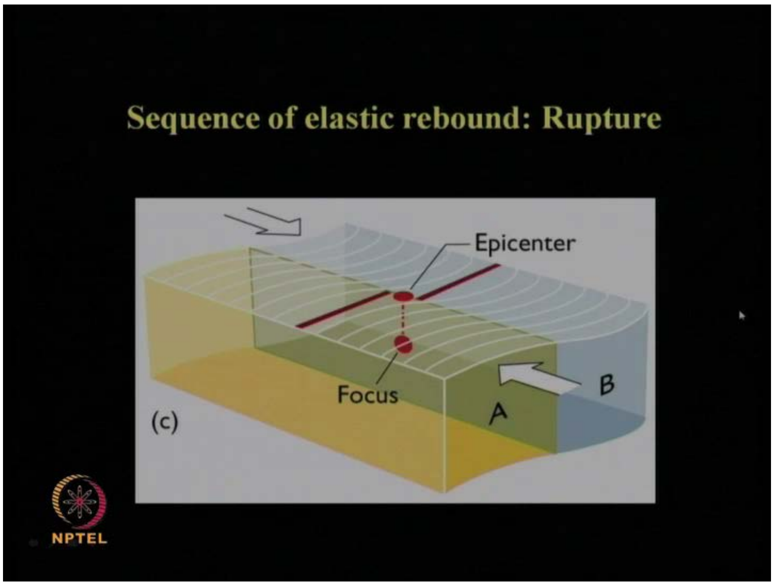

And in the next step, what will occur rupture. So, once this bending stresses getting developed within that rock exceeds the limit of the strength of the rock that is the limit up to which the rock can with stand a certain amount of stresses. So, when it goes beyond that amount of bending stresses what will happen, it will rupture subjecting to that amount of bending stress which crosses the limit of the strength of the rock. So, that is, what it shows in this picture during the earthquake, when there is a release of energy through this focus point and epicentre is the vertical projection that point on the ground surface. So, what happens these 2 ruptures are breaks at along this point of weakness along this line of weakness? So, there is a breaking. So, if you see your line on which you are observing those points you can clearly see there is a difference in the line has occurred through this process of rupture in this sequence of elastic rebound and the final stage is the rebound.

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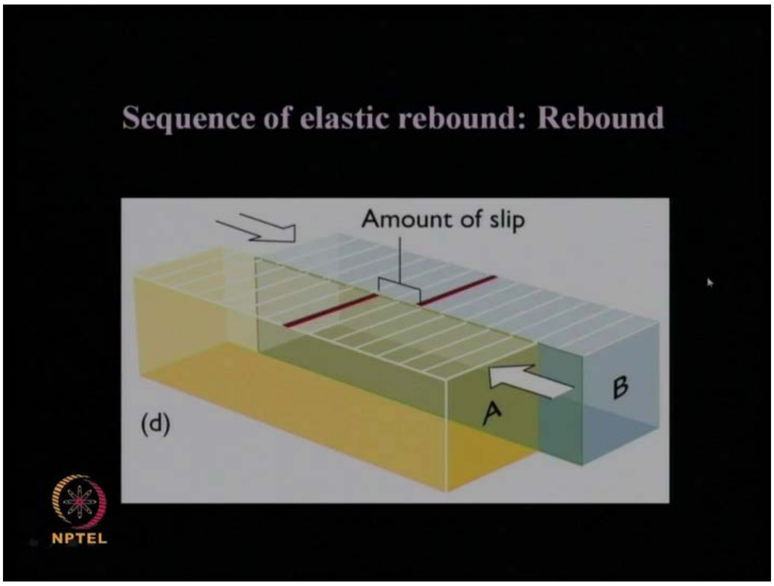

So, this is the last step on this elastic rebound that is finally, this block A and block B will become 2 distinct rock block, and they have moved by an amount of this much, which is known as the amount of slip or amount of movement or amount of displacement and they again goes to another state of equilibrium.

So, each of these blocks now goes to another state of equilibrium and living this line, red line on which we were monitoring, those points their movement etcetera. You can see now, they are completely shifted by certain amount which is nothing but the amount of slip. So, this elastic rebound theory; what are the steps we have seen first the stresses getting generated through which it goes to a bending of that rock, and when that bending stresses is more than the strength of the rock, then it ruptures along that line of weakness or fault and after the rupture that rebound occurs, and individual blocks goes to another state of equilibrium. So, through this process of elastic rebound theory, we can understand what are the various stages which are occurring during an earthquake.

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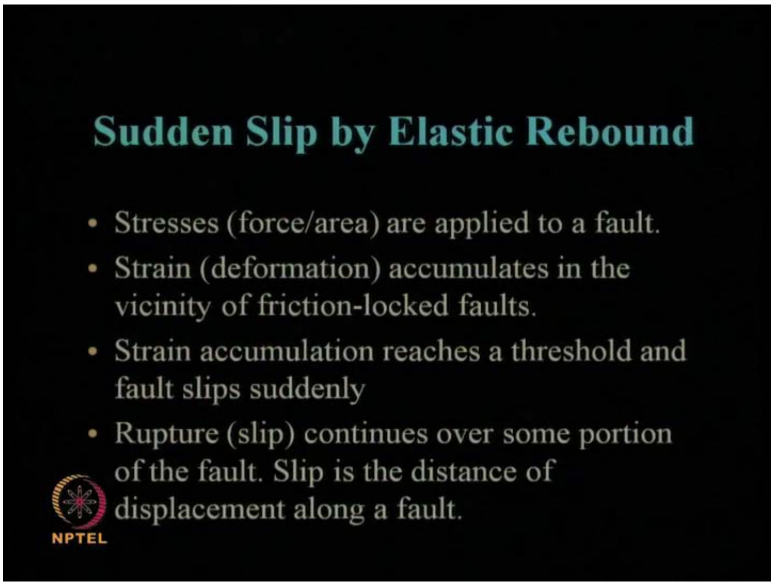

So, if we want to see the sudden slip occurs by elastic rebound; what we have learnt through this picture. So, first stresses are getting developed that is stresses are applied to a fault that is force per unit area. And that stresses automatically creates a strain or the deformation, which gets accumulated in the vicinity of the friction locked faults that is those are initially locked faults. There was no movement actually occurred in that faults, and that strain accumulation reaches a threshold value, and beyond that threshold value fault starts slipping suddenly along those point of weakness or fault.

And that rupture or slip continues over some portion of the fault, and that slip is the distance of displacement along a fault. So, that slip is nothing but the measurement of the movement through which 2 rock blocks slide past each other along that line of weakness or fault.

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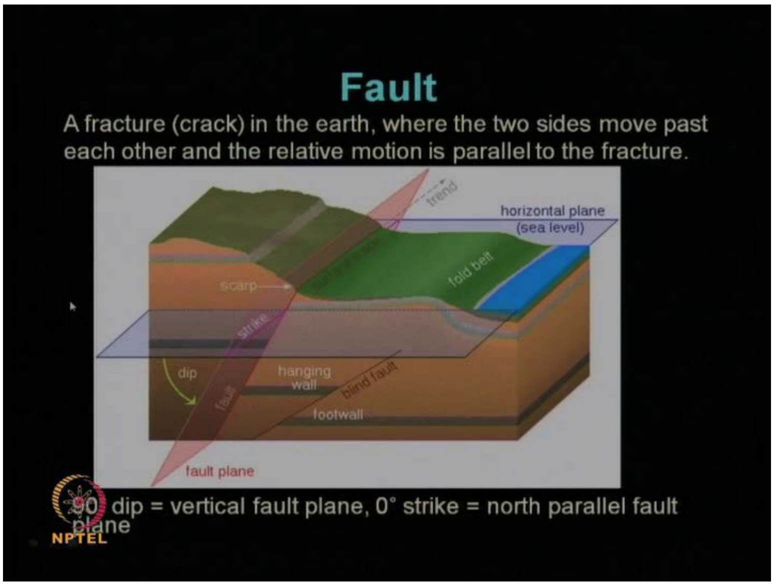

So, now, let us look at various characteristics of these faults. If we see at this picture fault is nothing but a fracture or crack in the earth where the 2 sides move past each other, and the relative motion is parallel to the fracture. So, that is nothing but fault. So, if we look at this picture; what it shows you can see over here; this is the ground surface; this plane is nothing. But the horizontal plane at the sea level, this plane has been mentioned now, when we have a fault or plane of weakness; this plane which is called as fault plane; this plane make some mark on this ground surface which is called the surface stress of the fault, and the angle, this vertical angle which it makes with the horizontal plane; this fault plane that is nothing but is known as dip and this one is called strike.

So, 90 degree, if this angle of dip is ninety degree that is for 90 degree deep, what we can say that the fault plane is a vertical plane quite obvious as you can see from this picture 90 degree fault plane means, it is a vertical plane, and if the strike angle this angle, if it is 0 degree; what it is called, it is called as north parallel fault plane.

So, for 0 degree strike it is called north parallel fault plane. So, these are the nomenclature. We use to identify the fault location at a particular place that is, we mention those fault planes in terms of their angle of dip, and angle of strike with respect to this horizontal plane. So, these are the common definitions or common parameters which are used by seismologist or geologist to identify the orientation of a fault plane with respect to the horizontal plane which is considered at the mean sea level. So, with this we have come to the end of this lecture. We will continue further in the next lecture.