Earth Sciences for Civil Engineering
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Module 3
Lecture No 13
Rock types and their Properties (Part-7)
&
Seismology and the internal structure of the Earth (Part-1)

Welcome back.

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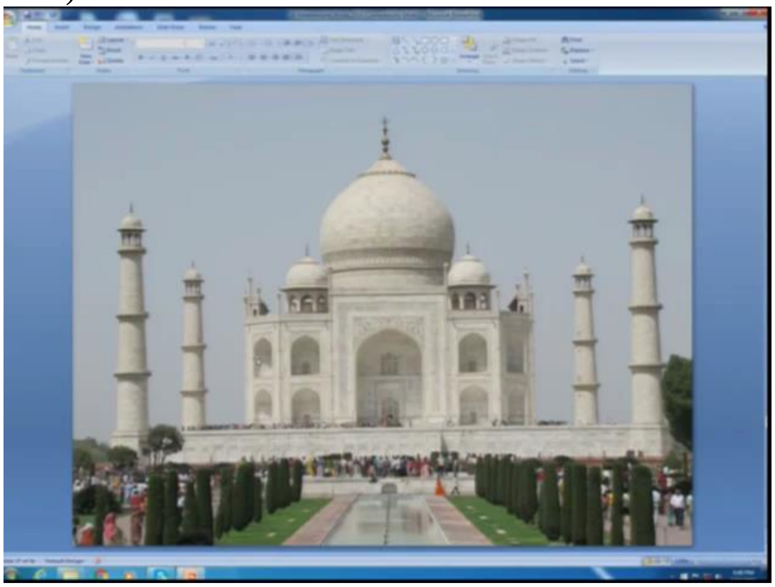

So in the previous lecture, we talked about the foliated and the non-foliated rocks and this is one of the best examples for non-foliated rocks that is marble. And we are fortunate to have such a beautiful monument in India which is completely made up of marble. And this is one of the reasons because marble is quite hard as compared to the other foliated rocks.

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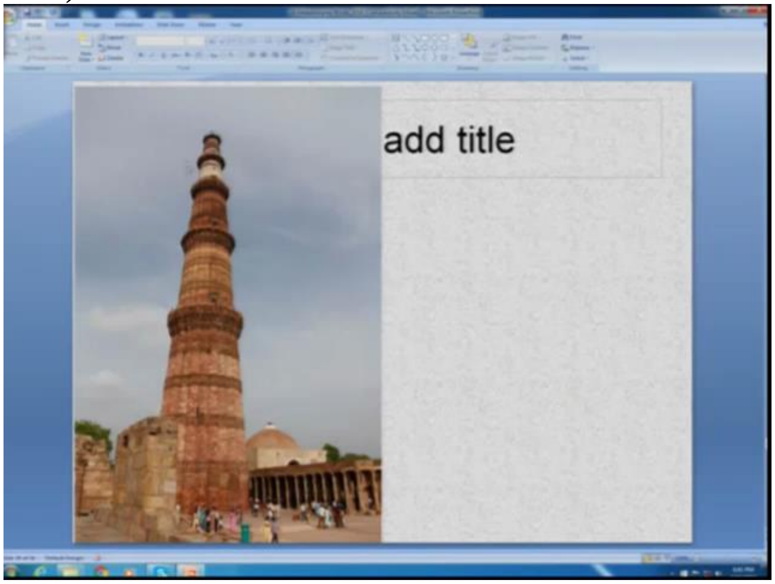

So let us move ahead. This is again a very beautiful internal structure of from Agra. Probably, not from Agra, this is from I think Red Fort. So this is the picture of that, again made up of marble and the upper storey here we are having that is also made up of marble, of Qutub Minar.

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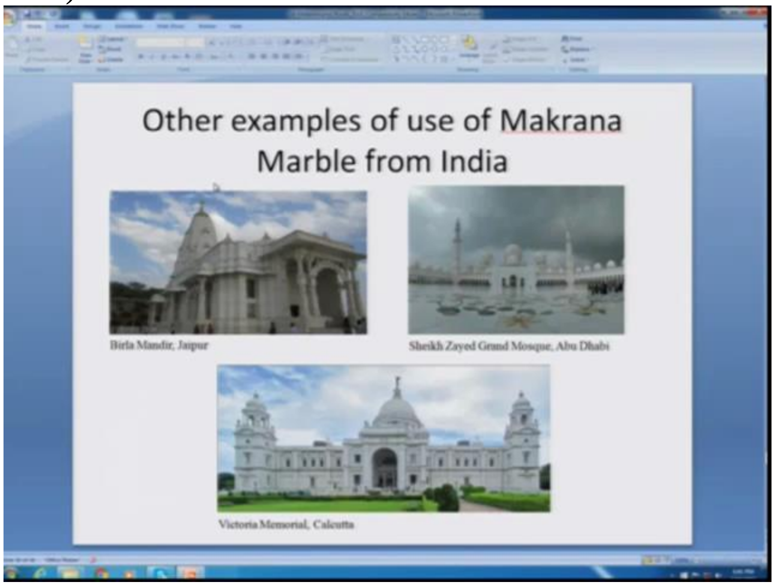

And then we are having other examples which used the Makrana marbles from India. The temple in Birla mandir in Jaipur and then we have the famous mosque in Abu Dhabi and then we have the Victoria Memorial in Kolkata. So these are all monuments which were been made using the marble from Makran Makrana marbles.

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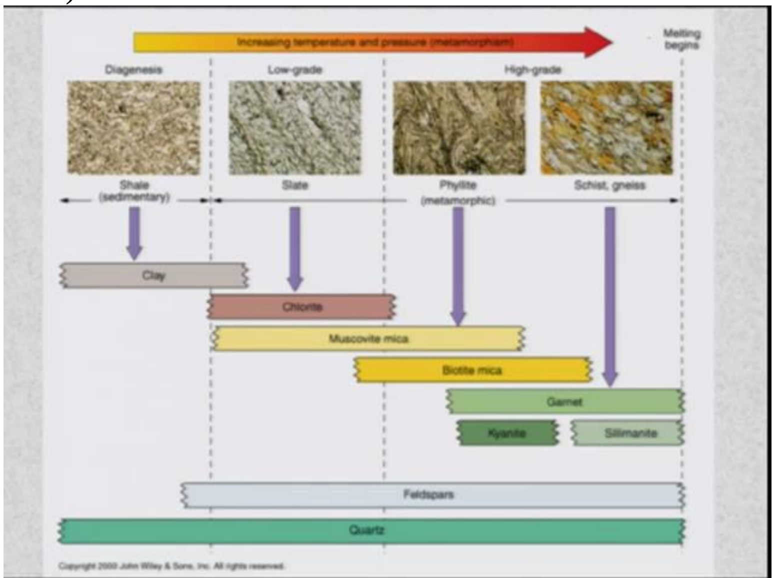

So again very quickly if we look at the increase in temperature and pressure, how it affects the formation of different type of rocks, so for example, the process here has been termed as, you are having diagenesis, you are having low-grade metamorphism and you are having high-grade metamorphism. So when you have for example the shale which is the sedimentary rock.

So if you are having the shale here which is a sedimentary rock and when it is subjected to the low-grade metamorphism, it will result into the formation of slate. Further if you move towards the high-grade metamorphism or within high-grade and low-grade, you will have phylites and further maximum in high-grade, you will have schist and Gneiss.

So this is what were talking about the for wavy texture and this we are having the sistose texture. So sistosity will be seen very where you are having the slightly larger grains and you are having the foliations of the platy minerals. So you have, if the composition if you take, you will have clay and you are getting into chlorite, Muscovite and then biotite, mica, garnet, kyanite and sillimanite and then most of these rocks, you will have quartz and feldspar which has been seen.

And then if you move from your left towards the right, you are getting into the high increase in metamorphic metamorphism that is increase in temperature and pressure. Getting from low-grade to high-grade metamorphism. And of course, there is the last point, if you go deeper into the earth you are having, you are reaching into the where the melting of rocks will start.

Please remember this and you can refer the 2nd slide or the 3rd slide where were talking about the different type of rocks when they are subjected to like shale to slate and then phylites and then schist and all that. So of course this depends on what you are putting in. So if you are having sandstone which is rich in quartz and feldspar, you will have out products will be quartzite.

And if you are having limestone then you are having the out product is marble here. So those are the different types of different types of what we are talking about, non-foliated and foliated rocks.

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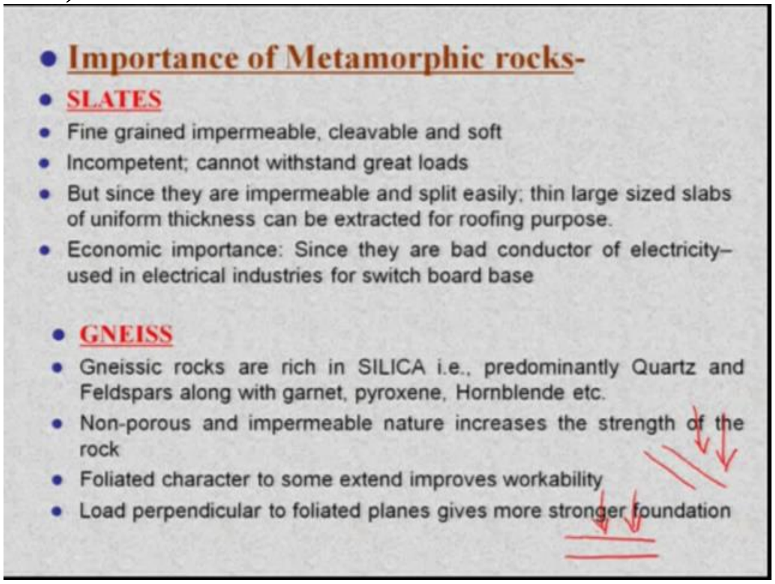

Now with that that understanding, let us look at what is the importance of those rocks. How they are we can say that this is the massive, hot rocks or they are soft rocks and whether they will be subjected to the very fast erosion or not. We will see that. For example slates as we have talked about that these are these are these slates are are the product of your shale and shale is the argillaceous sedimentary rocks. So they are having the clay minerals, abundant clay minerals in that.

So they are definitely argillaceous fine-grained rocks, shale and when they are subjected to metamorphism, they will result into the formation of slates and slates are foliated rocks. So they are fine-grained, impermeable, cleavable and soft in nature. Incompetent, cannot withstand great load. So if you are having come coming across slates, you should avoid putting any heavy structures on that.

But since they are impermeable and split easily, thin, large sized slabs of uniform thickness. This is because of its typical platy nature for the cleavable planes you are having. So you have you can excavate or extract the thin large size slabs. And which people have used for roofing purposes. So in many places or the many states use this as to put the roof as roofing purposes.

Economic importance. Since they are bad conductor of electricity, used electrical industries for switch gear boards and all that. Now coming to Gneiss. Gneiss rocks are rich in silica. And that is predominantly quartz and feldspar along with garnet, pyroxene and homblende. Nonporous and impermeable nature increases the strength of the rocks. So this is comparatively having better strength than this one.

Foliated characteristics to some extent improve the workability. So they are also easily workable so as compared to what we see the Gneiss. Load perpendicular to the foliation. Foliated plains give more strength or stronger foundation. So this is one one advantage of this one. So Load perpendicular to the foliations, gives more stronger foundation. But if they are inclined, if their load is inclined, then you will have problems.

So is the foliations are like this and you are putting a lot of load here, then they will result into the slipping of that. So it may result into the slipping but if you are having perpendicular then you are having the load here. There is no problem in that sense.

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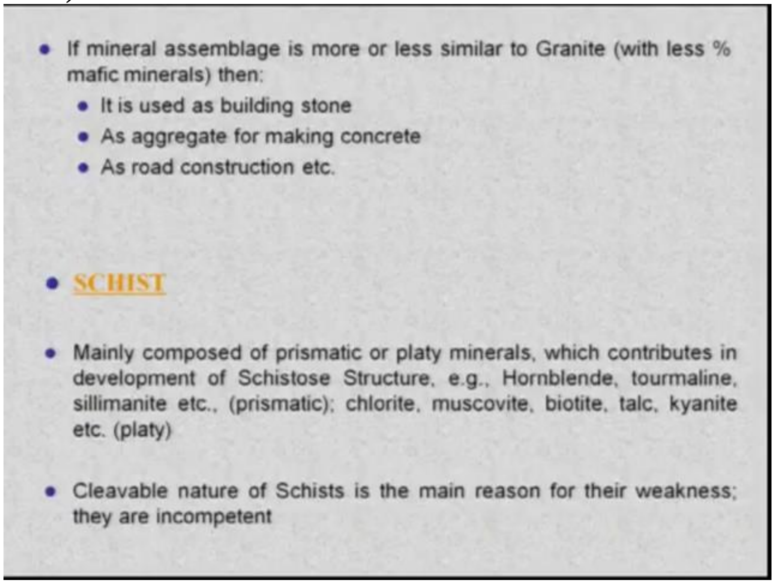

So if mineral assemblage is more or less similar to granite with less mafic minerals. So they are having more felsic minerals here. The granites mostly the igneous rocks are having so and if you are having Gneiss which is granitic Gneiss, it is also used as building stone. Also aggregate for making concretes, as road construction, etc. And then you have schist. So this were talking about the granitic Gneiss.

So if the composition of the Gneiss is very much similar to granite then they can be used as building stone, for making concrete aggregates and all that. Now coming to the schist, mainly composed of prismatic or platy minerals sister which contributes in development of the schistose structure. Example, the minerals are hornblende, tourmaline, sillimanite and then you are having chlorite, Muscovite, biotite, kyanite and all that. So these are platy minerals.

So cleavable nature of schist is the main reason for their weakness. So they are easily cleavable and hence they are incompetent in nature as compared to the Gneiss. It can slide.

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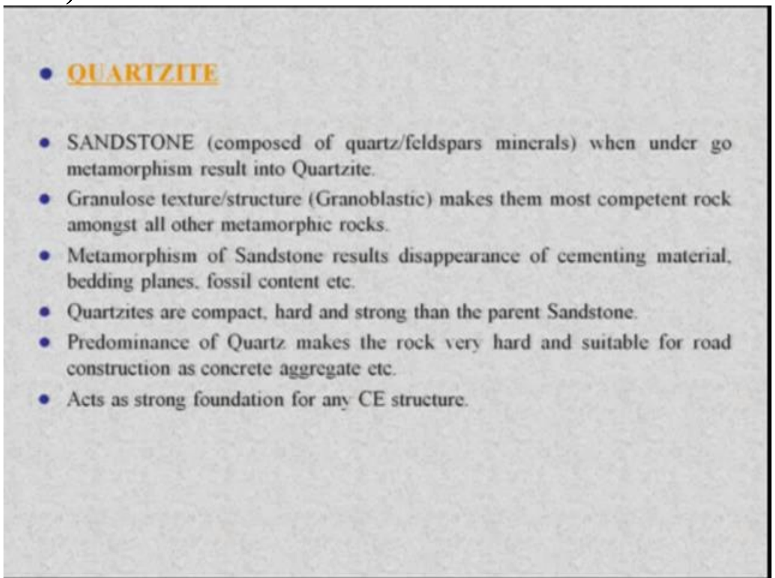

Then coming to the quartzite as were talking about that the interlocking of the grains is very much they are what we call very high and what we call the granulose texture type we will see. So sandstone composed of quartz and feldspar mineral men undergo metamorphism will result into the formation of quartzite is. So granulose textures, we have structures which we also term as granoblastic texture or granulose texture, makes them more competent rocks amongst all other metamorphic rocks.

So they are massive, very hard. So metamorphic rocks, metamorphic sandstone results disappearance of the cementing material, bedding planes and fossils content if any in that. And then result into the formation of quartzite you are having which is very much most competent rocks of the metamorphic rocks.

So quartzites are compact, hard and strong than the parent sandstone also. Because we do not see any pore space, everything is being squeezed out. So predominant of quartz makes the rock very hard, suitable for road construction and concrete aggregates. Now if you look at, nowadays that most of the quarries you are having is they are they are trying to quarry the gravels from the older river beds.

And in Punjab and all that, most of they are using the quartzitic pebbles. So they are breaking into the aggregates and using that aggregates for the construction of roads and all that. So the roads which are being constructed using these aggregates, that is mainly of quartzites from quartzitic pebbles or quartzitic gravels will have more more durability as compared to when they are been made, the roads are made using the aggregates which are from the basaltic rocks or the igneous rocks.

So they act as an good foundation for the CE structures. So this is one of the best example of quartzite which we see. So I stop here. So we have talked about the different types of stocks and from my next lecture, I will start and talk about the seismic interior and related to earthquakes and then we will talk about the seismic, different types of seismic waves and the related hazards and all.

So now this is another part of this course which is extremely important and here we will talk about the interior of Earth.

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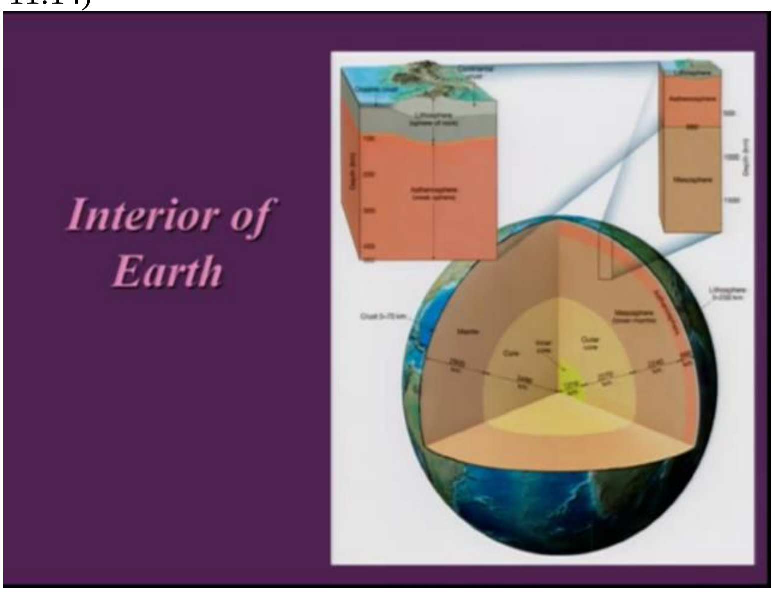

Partly we discussed, were talking about the plate tectonics. Now we will talk about the seismic waves, we will talk about the earthquakes and how different seismic waves are affecting when they are produced during the earthquake. So interior of Earth we take, we understand and we know that the interior of Earth is not homogeneous. It is having different layers and of different density and different composition.

Now, how seismi is played an important role to identify and to know the interior of Earth? That is interior of Earth is not homogeneous but it is having different composition and different density.

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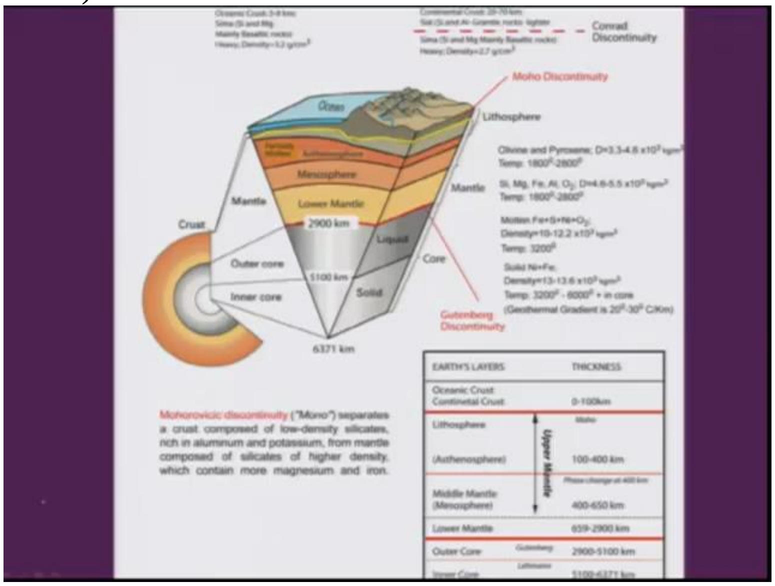

So this will discussed on that day, during the initial lecture on plate tectonics that we have the different materials. Even we have like the oceanic crust and the Continental crust and oceanic crusts are heavier as compared to the Continental crust. Oceanic crusts are mainly comprised of silica and magnesium rocks. Whereas the Continental crust, we have silica aluminium and silica magnesium rocks, silica and magnesium rich rocks.

So they are comparatively lighter whereas the oceanic rocks are comparatively heavier. And then we are having different discontinuities between the major and minor layers within the interior. So if we divide the interior of Earth in the main sections, so what we are having? Core, mantle and crust mainly. And then we are having further categorisations or we are having inner core, then we are having outer core and then we are having mantle where the mantle comprises of lower mantle, then middle mantle or mesosphere.

Then we are having asthenosphere and then we are having the lithosphere part. And the top part what we see is the crust. And then pass over here. So we have different layers and we, these were been identified using or with the help of the seismic waves. So let us move ahead and then see what so this I will just faster. We have already discussed. But I would again request you to go through this which will help you in understanding the interior of Earth.

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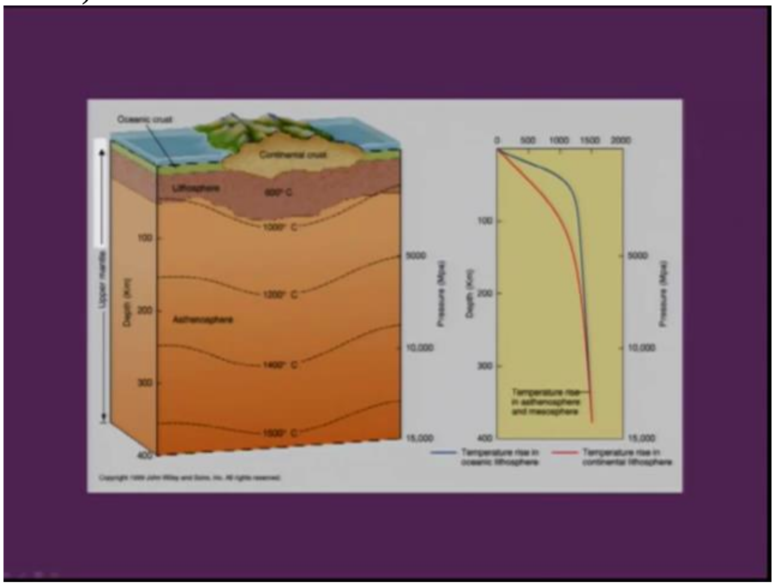

So as we go deeper into the interior of Earth, we understand the temperature increases along with the as we move towards the interior of Earth and pressure also increases. And these are the 2 graphs which shows the curves, which shows the increase in temperature, rise of the Continental lithosphere and here we are having the rise and the of the temperature when we look at the oceanic crust mainly. And this red one is your Continental lithosphere.

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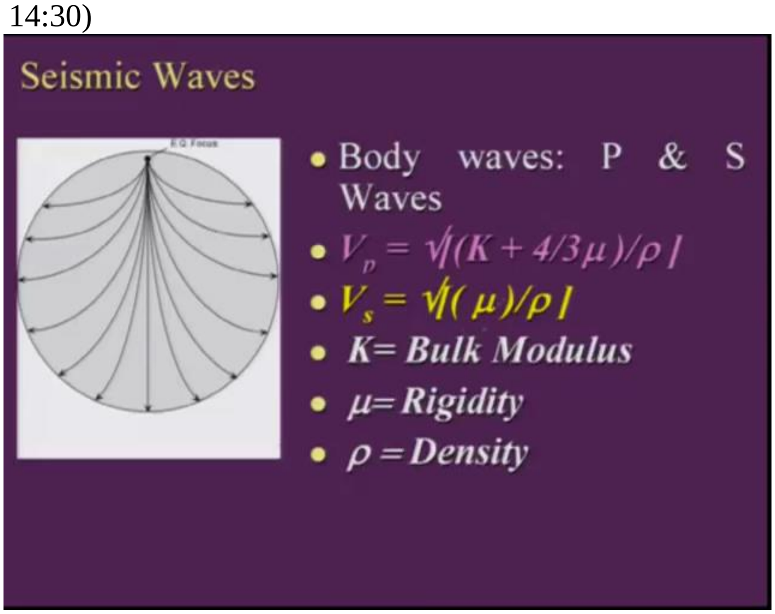

So seismic wave basically we will see what different type of seismic waves are. Now if we would we would have the interior of the Earth as homogeneous, then any earthquake which would have triggered at any locations then the seismic would have travelled like this. But we do not see this. We do not see that very systematic path, travel path of the seismic waves in the interior of Earth.

So if you look at the different types of waves, we have the body waves which we call primary and secondary waves, P and S waves. And if you look at the equations, we are having the P waves and S waves, the velocity equations. So the most important here is what we see the shave of modulus of shave and the and then this one is the bulk modulus we are having and this is the module is of rigidity.

And this plays an important role in terms of the S waves. We will discuss about this one. So we have the density here. So it the velocity will be affected by the density, it will be affected by the rigidity of the material.

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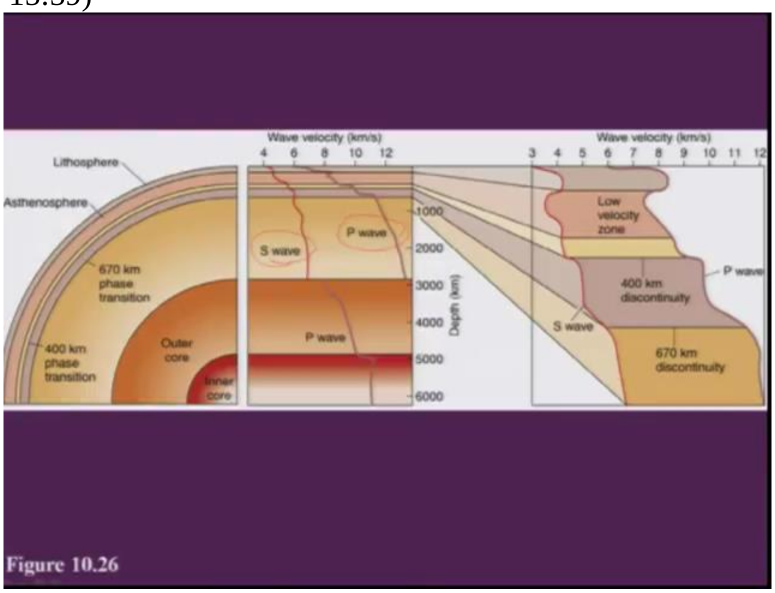

Figure 10.26

So here if you look at the interior of the Earth, we are having the P waves and the S waves which are travelling into the interior of the Earth but the velocity changes as you move further into the interior of the Earth. So the slowly it increases here but at some places it is like dying out and then you are having, it does not travel further. Whereas here in terms of the P waves, it increases and increases and goes right up to the 11 to 12 km per second and then it reaches further high that is in this zone.

And then you are having further it reduces and then so the velocity reduces because of the change in the density or the composition between the other mantle and the core boundary here and then further it slowly increases and so on and passes through the interior of Earth, that is the inner core side. And we know that the is this is liquid compared to what we are having completely solid in our core.

So look at the upper part, it is around thousand kilometres of the cross-section, what you see here is you are having the change in the velocity here at this part. So you are having this zone what vitamins the low velocities one and this is representing your asthenosphere. So both the seismic waves which has an speed or the velocity in the crust and this is an S wave having 3 km per second and this one is around 6 km per second, it reduces here sharply and then further it gains.

And then it travels. Again, it regains and travels into the interior of Earth but this is this is lost here. It is not transmitted further into the interior of Earth. But this has a capability again and this all depends on the nature how it propagates. So these are having the S waves and P waves are having very different nature of propagation. So that we will try to learn here. What is the nature of propagation?

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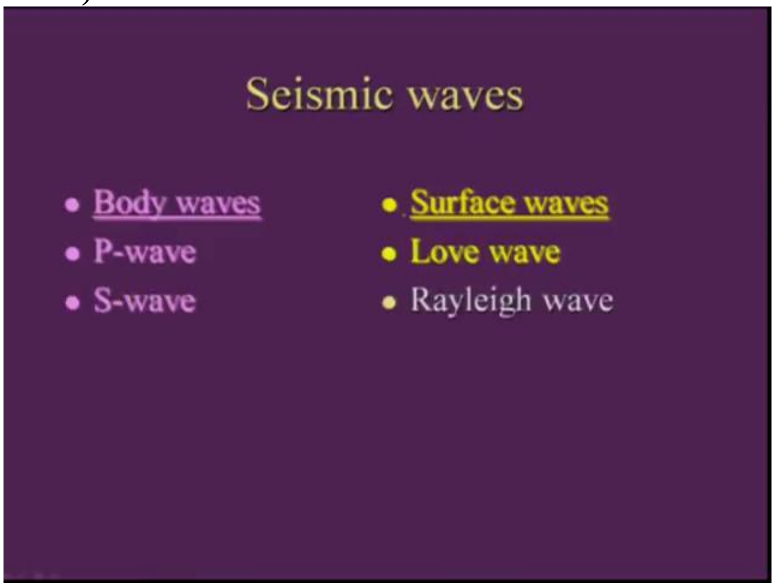

So further I had seismic waves. We have body waves and we have where we have P waves and S waves. And then surface waves, we have love and rayleigh waves.

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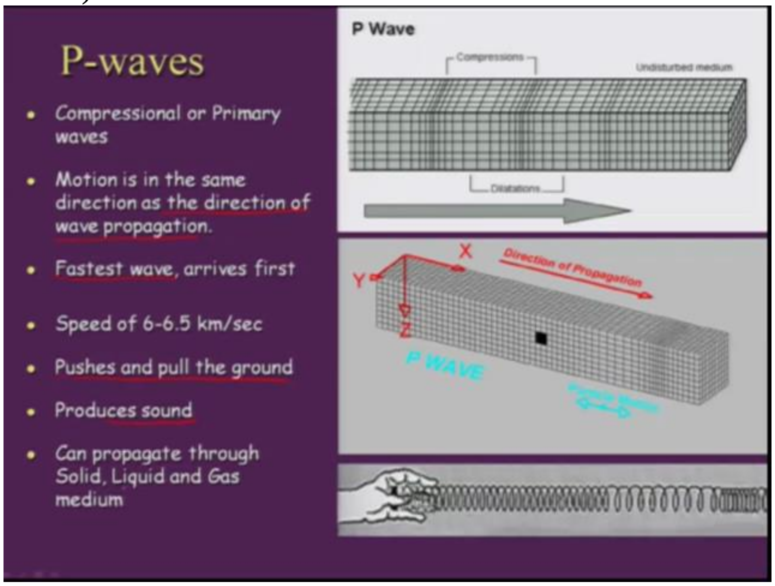

So P waves basically the motion, the direction of propagation if you look at is almost in the compressional fashion. So if you push and pull any material, it is very much similar to that. So if you hold the spring here and then try to push and pull so if you are having that it will travel the particle in this direction. So the movement is in direction of propagation but it will pull and push and pull the particles.

So this you will have in a very typical nature here. So they are basically the compressional waves or we term that as primary waves. The motion is in same direction as the direction of propagation. Fastest wave it arrives 1st. Then we are having the speed is almost like this km or 6.5 km per second. It pushes and pulls the ground. Produces sound.

So the movement it is like like what the motion is very much similar to the sound waves. Hence it will result in to the it creates sound when it is propagated into the atmosphere or within the Earth's surface. You can hear sound when these waves are propagating. It can propagate through solid, liquid and gas media.

So it can propagate through any medium. It is not having the restriction of propagating through any particular medium because of its maker. So it produces, these are the typical very important points which you should remember. So these are the fastest waves. They propagate in the direction of propagation or the motion is almost like in the same direction of the propagation.

They pushes and pulls the ground and they can propagate through any medium like solid liquid and gas.

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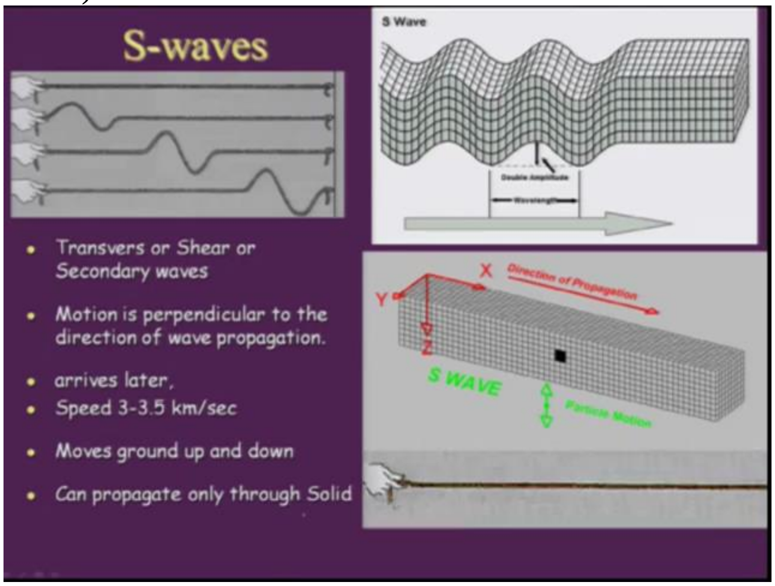

Then another one is what we call the S waves or we also term that as transverse waves. So if you hold the rope and fix on the other side and wave up, so it will travel in a in a very typical fashion moving the rope up and down and then propagate in the direction of propagation. So this is the typical of what we see the primary, sorry secondary waves. So it will move the land surface up and down when it is moving.

So it is also termed as the sheer waves or the transverse waves or the secondary waves. Motion is perpendicular to the direction of wave propagation. And the P waves were having almost in the direction of propagation. This is having the perpendicular direction and then arrives later because they are slow speed. Speed is slow, almost half, 3 to 3.5 km per second and moves the ground up and down and can propagate only through solids.

So this here is the most important part where we are talking about the shearing part. So, shearing will not take place in liquid. Hence it will not allow the these waves to propagate further. So **it** the there is a dampening effect. The energy will be completely lost. It will not propagate further because of its nature of propagation.

So it shear and the shearing is not taking place. Whereas in the case of the P waves, we are having push and pull. So it moves in the direction of propagation. Hence it can go through with lesser speed also. It can go through the different types of materials or the medium but here, this does not move in other medium other than only it can go through solid.

So this is another ripple characteristic of the secondary waves or we can say shear waves or transverse waves. So motion is perpendicular to the direction of wave propagation having comparatively lesser speed almost like half I have in the crust and then moves the ground up and down. It can trouble get only through solids. So this you should remember about the difference between the P and the S waves.

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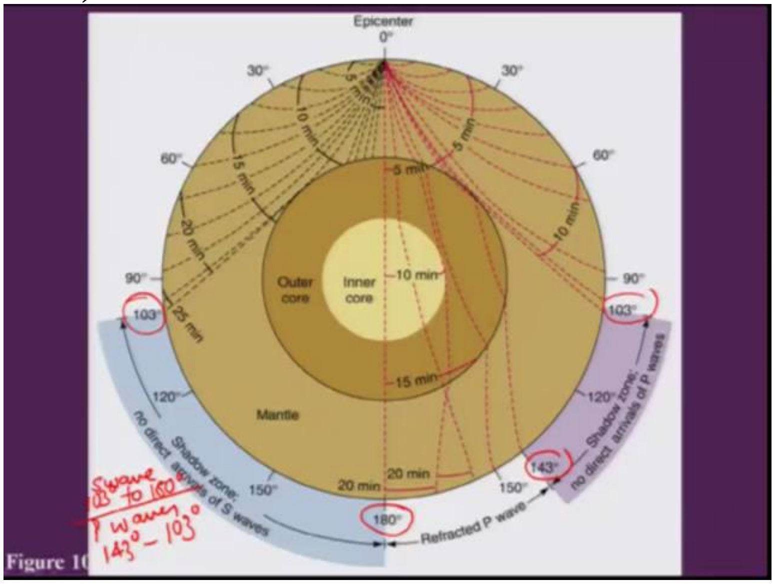

Now if you look at the interior of Earth and if you for example say that the earthquake was triggered at 0 degree then what you will see is that propagation as we have discussed that not always will go through the interior of Earth. Some are reflected, some are reflected back. So if you look at these black lines, all are having you are having these are S waves, these are P waves we are having.

So what we see, because the velocity of P waves changes at the different contact and the contact between the mantle and the outer core, the outer core which is liquid in form and so the S waves will not go through whereas the P waves which are coming here slows down and that what we call, it will be slightly deflected and then we are having further refracted ones which are reaching and this in this location.

So only what we see, the arrival or the recording of the P waves in this area is we see is because of the what we are getting the refracted P waves. But no S waves we will be able to see in this region. So no S waves are been seen here. Only the only the P waves are been seen in this area. So what we term this region so we are having like shadows zones.

We say this as a shadow zone. So ma and this shadow zone from 103 to 180 is complete shadow zone of the S waves. So no S wave will be seen between like one 103 to 180 but between 180 and 143, you will be able to catch P waves which are refracted P waves. But again between 143 and 103, because of the deflection of the P waves, you will again not be able to see the P waves in this region.

So the important is that we are having the shadows zones of the S waves. You are having from 103 degrees to 180. And you are having the shadow zone of the this is S waves and then you are having P waves are having from 143 degrees to 103 degrees. So this you should remember about the shadows zones of different waves.

So this is all like very well seen or observed when an earthquake is triggered at one location. And some stations will be able to record the partial P waves whereas some locations or some stations will absolutely not been able to record the S waves in that region.

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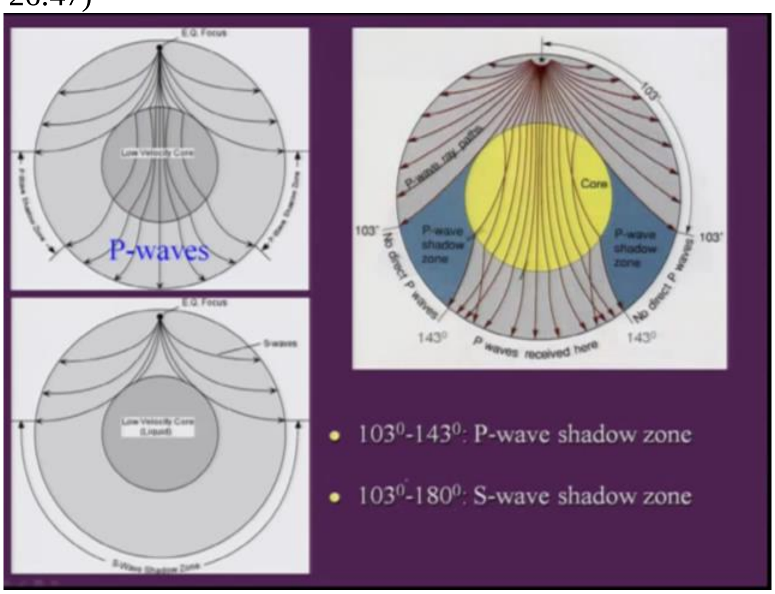

So this is an the example which has been which were talking about. So here, we will not see any direct P waves as we term this as a P waves shadow zone. And then so that is 103 to 143 is P waves shadow zone and from 103 to 180 degrees we are having S wave shadow zone because S wave will not go through the core. They are been deflected from the from the outer that is the contact between the mantle and the core.

So they will be seen only in this region. They will not be seen in this area. So you are not having any S wave which is coming into this area. Whereas some P waves will be seen we will be getting in this one but leaving this part as in shadow zone. This we are having, between 103 to 143 is the shadow zone for the P waves. And the S wave remains completely from 103 fried up to 180.

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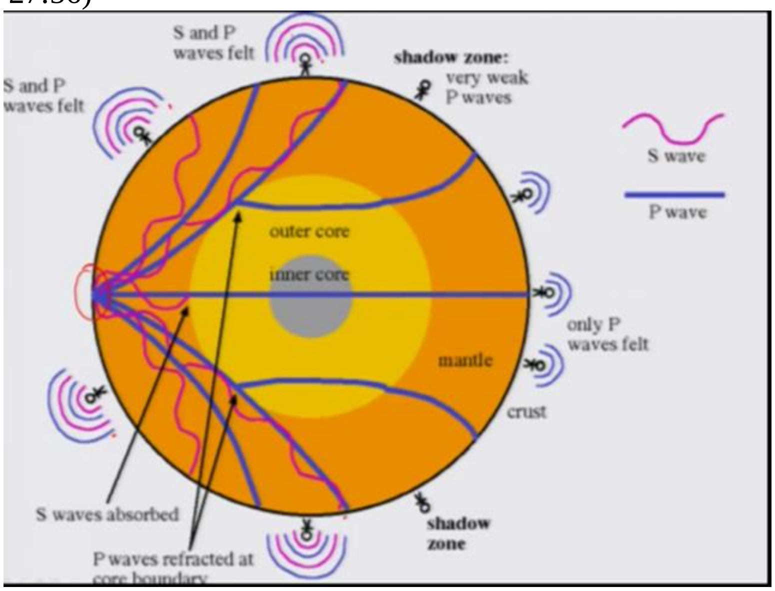

Now for example, you trigger an earthquake over here and then what will happen? So we are having the pink ones is your S waves and blue ones are your P waves. So the stations which are located here, this one, this one here, this one and this one, they will record both, P and S waves. And here what we see are some of the P waves are refracted and you are having the P waves which are been raging here.

So stations which are sitting just opposite to this, what we have been talking between between 143 and 180 will all receive your P waves. But no P waves here, no S waves here right from this to this one. But these stations will have will be fortunate enough to receive all the waves, that is the P and S waves. So this is what we find and we observe in big earthquake or even the smaller earthquake occurs on the Earth.

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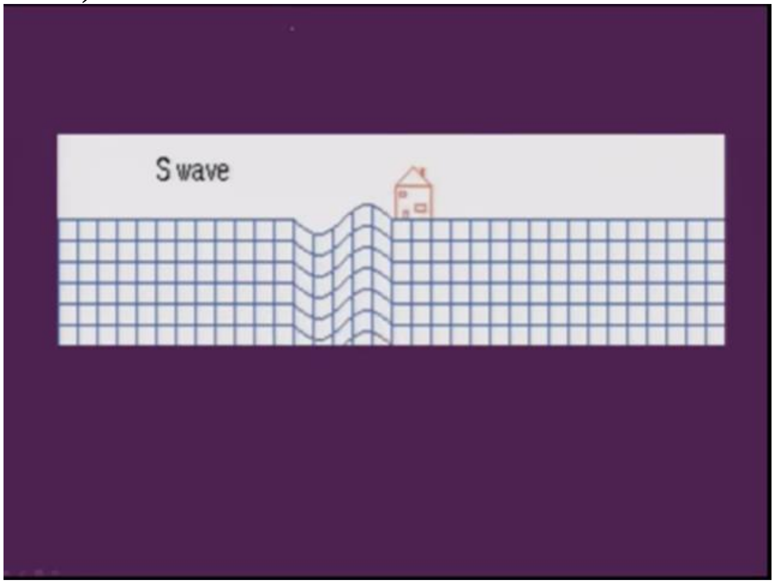

Now S waves as we have been talking about that they will move the surface up and down. So they will damage the civil structures which are sitting on the surface.

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So it will most surface up and down in the direction of propagation.

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And this is one of the examples of 1999 Chechi earthquake of Taiwan where you can see the passage of S wave across the across the area. So which resulted into up-and-down here you see because of the S wave.

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And this is the photograph of 2001 Bhuj earthquake in Kutch which is resulted in to the preservation of the S wave. So waved up surface if you take here, this is a bridge which shows a very beautiful preservation of the passage of the S wave here. This is on the bridge.

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And this is on the ground we are watching. So if you carefully watch this, there is up here, down here, up here. So this is typical of the passage of the S wave which will result into the up-and-down movement of the ground surface.

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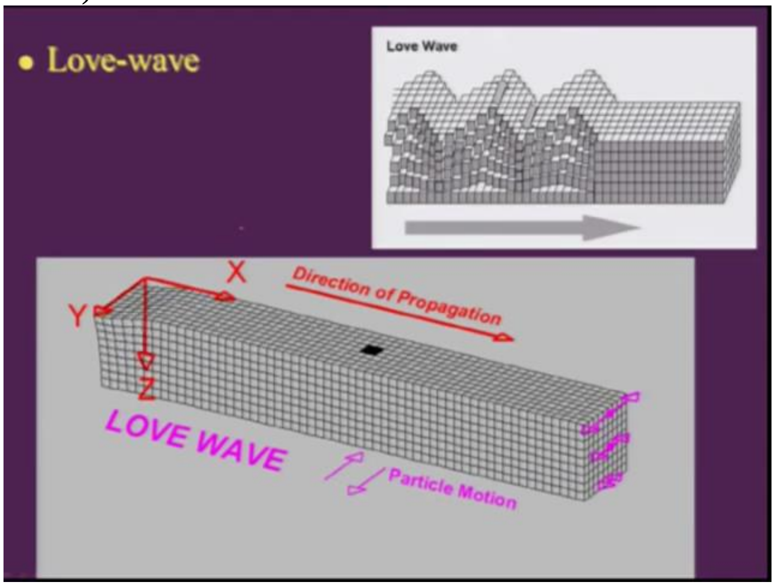

Then of course, we are having other waves which we say the surface waves which are done generated and the later stage and they all mostly travel along the surface of the crust and they are termed as the surface waves. The love waves are having very typical motion which has an mixture of both. So you are having the particles will move side-by-side as compared to what we have seen in the other place. So you are having the love waves.

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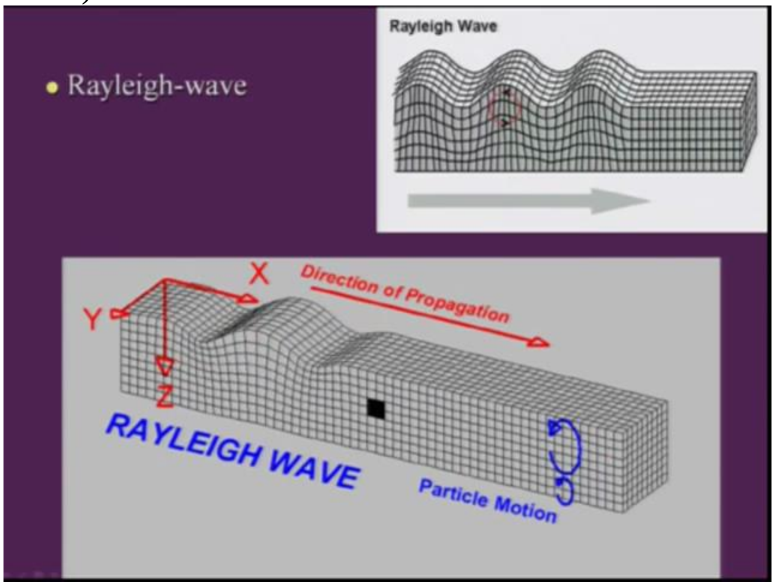

And the rayleigh waves if you look at, is having an elliptical motion. So it will have, particle will be rolled in an elliptical motion. So if you remember, all for waves which are the part of the body waves and the surface waves.

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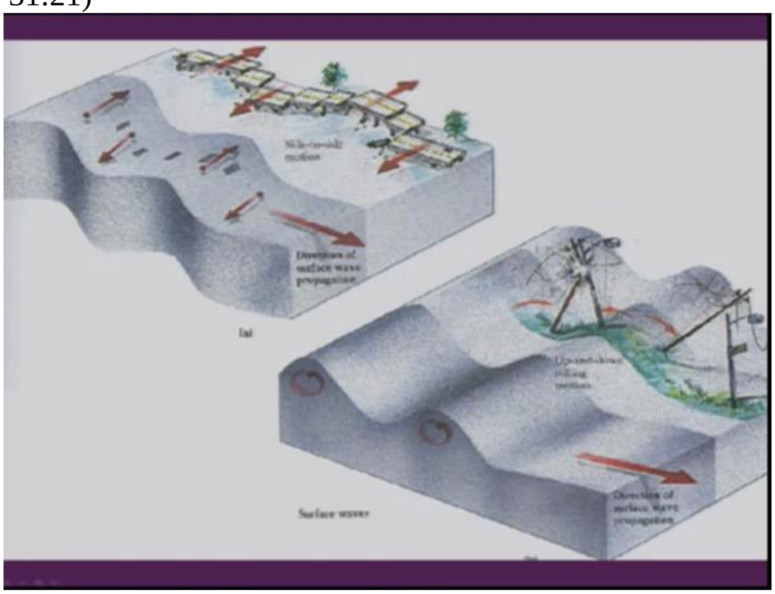

So none of the motion is been left out. So either via having the motion which is side-by-side which moves or it is moving in elliptical. This is an love surface wave. This is an love wave and this is an rayleigh wave and the previously we had seen that they are moving back and forth. Then we are having up-and-down.

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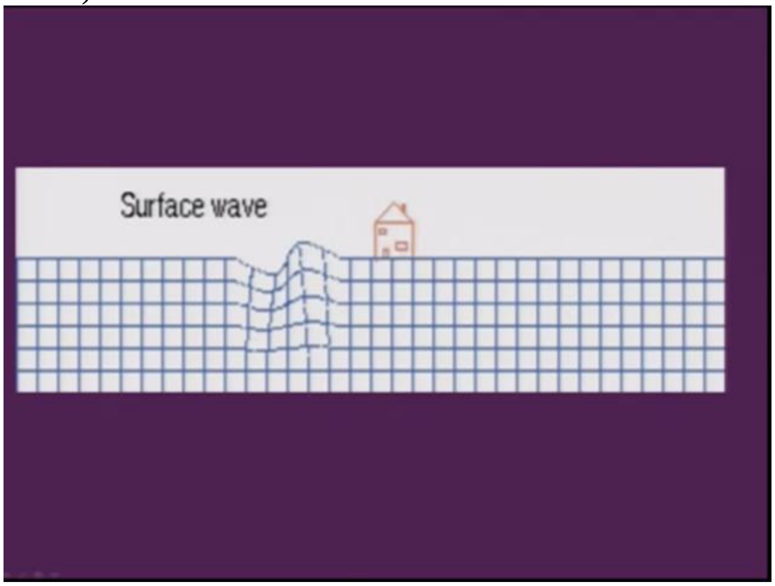

So in short, surface wave will not leave any structure on the surface. It will be completely destroyed. So the S wave when it is propagated, we at least see some structure is left out partially damaged but this will result into total damage.

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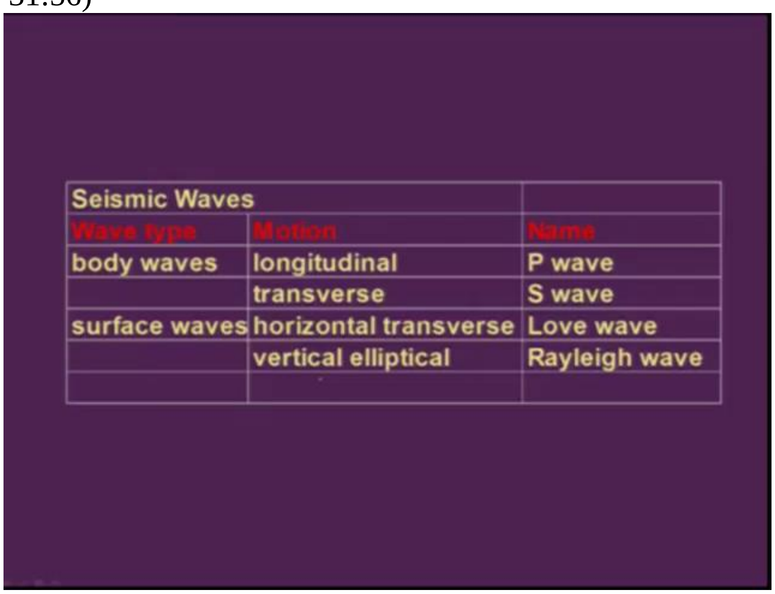

Seismic Waves		
Wave type	Motion	Name
body waves	longitudinal	P wave
	transverse	S wave
surface waves	horizontal transverse	Love wave
	vertical elliptical	Rayleigh wave

So if you look at the compilation of this seismic waves what we are having the wave type. Then we are having motion and then the terminology which has been given or the names which have been assigned to these waves. So we are having in broader sense, we have body waves, we have surface waves, motion is longitudinal transverse. That is for the P wave it is longitudinal, S wave, it is transverse.

Surface waves. For the love wave, we are having horizontal transverse motion and for rayleigh wave, we have elliptical. So in total, we are not left out from any side. All types of motion should be experienced at the time of an earthquake. And also we try to remember the most important characteristics of the P wave is that it will produce sound.

Whereas the and then again P wave will not be able to pass through the liquid medium. So this is again Zack sorry the S wave will not be able to go through that. So if you look at, just refer to this part, this is an important sections which you should remember. And then we can move ahead into the (())(33:09).

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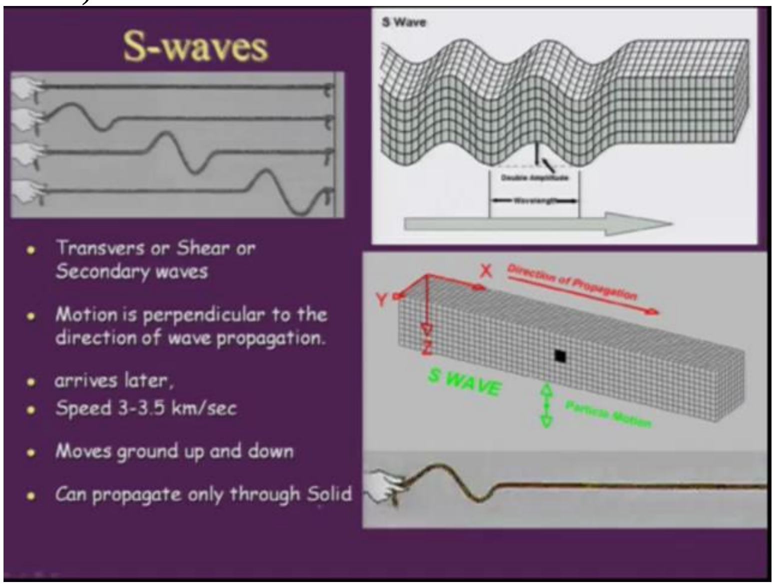

So the S wave can only propagate through solids. Soldiers you should remember.

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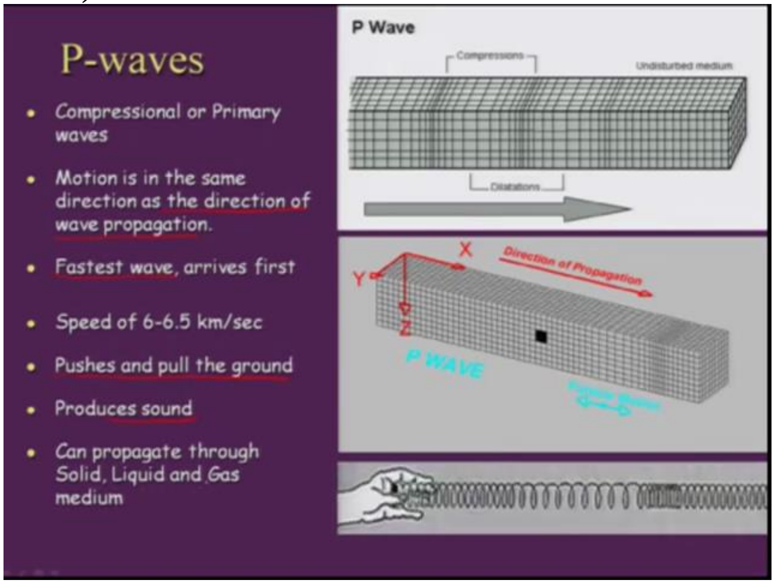

And the P wave what were talking about, the most important part is that it can propagate through all. So P will propagate through liquid, gas and medium gas medium and then it has a typical characteristic of producing sound here. Whereas the other waves are ok. So this will result in to the motion back and forth and this will move the land surface of and down, passes only through the.

Then this we have talked about. So we will just move ahead. So in short, if you look at the type of motions, we have been not left out with anyone, any kind of that. We have, we see all. Longitudinal, transverse, horizontal, vertical, elliptical.

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So this we experienced at the time of the phenomena which we termed as an earthquake.

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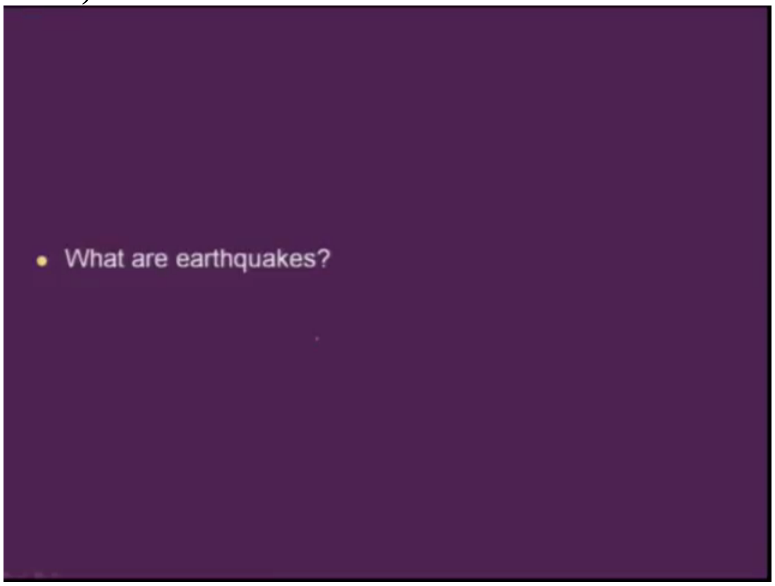

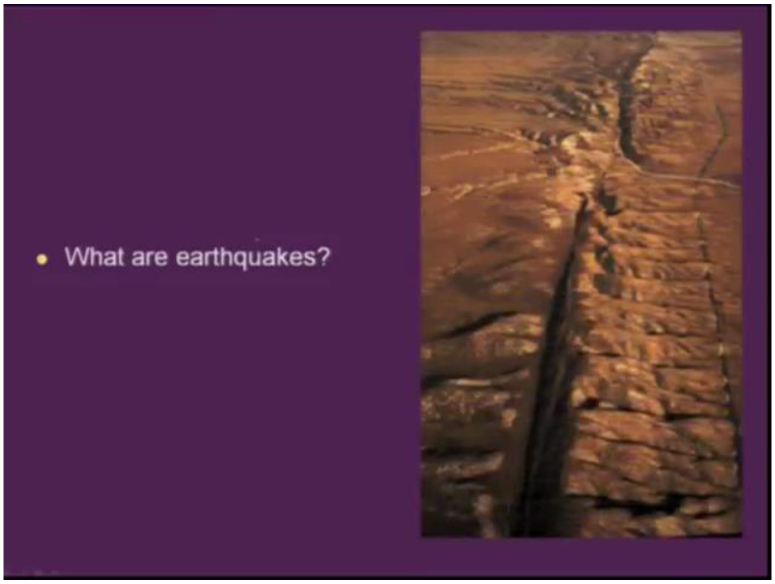

So earthquake in short, what are the earthquakes? What what? The deformation or this is a the what what we the process we termed as an earthquake is? That sudden release of stored energy which will result into the vibrations. And the earthquakes are seen occurring along the weak zones of the earth's surface. So experience the sudden release of an energy that will result into the ground shaking and that process is termed as an earthquake.

So this is an example of the very famous for system. We will talk about this in our following lectures what are different types of faults? But these are the weak zones on the earth's surface. So whenever there is an earthquake, there is a displacement of the within the crust. So rocks are moved and they will have some sort of a displacement experience during an earthquake and that displacement will be manifested along the surface.

So manifestation of the Crystal deformation on the crust is termed as fault lines. So this we will see what are the different types of fault lines. This is a famous fault line of what we say St Andrea's fault system in US.

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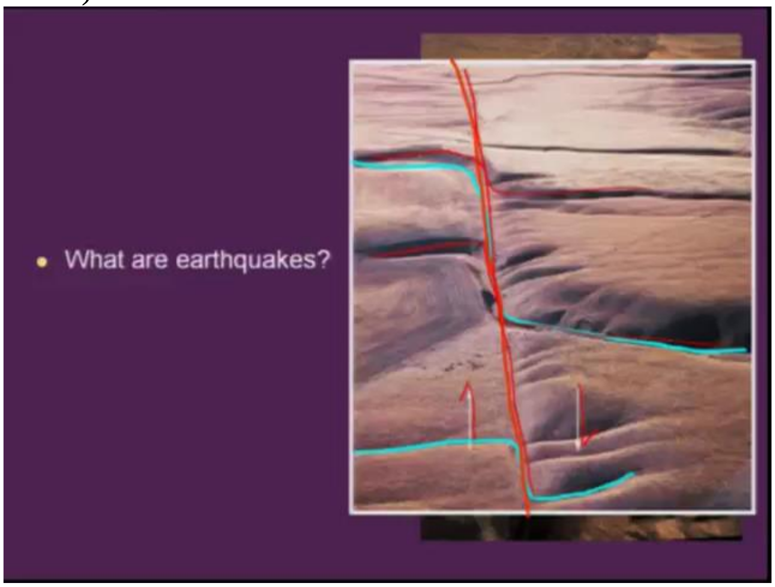

Then again, the same photograph which shows the that over the time then there is an because earthquake is a repeated process which will keep reccurring again and again on the weak zone and it will keep deforming the this the land surface. So the movement which has been which gets preserved on the earth's surface along a typical weak zone which we term as a fault line and here what has happened is that there was an earthquake or a displacement or a deformation which has been manifested along the surface, has displaced the landforms over the over the surface, earth's surface.

And the landforms are, displaced or deform the landforms are preserved. For example, here even the streams which are flowing are are deflected because there is a movement along the fault which is moving in the boundary over here. There is a boundary between the 2 blocks which have moved.

So this block has moved towards us and this block has moved away from us resulting into the deflection of the streams. So these are all deflected streams we can see here. So this is the longest one we are having and then we are having this shortest one here. And then these are fault lines which we can see on the earth's surface.

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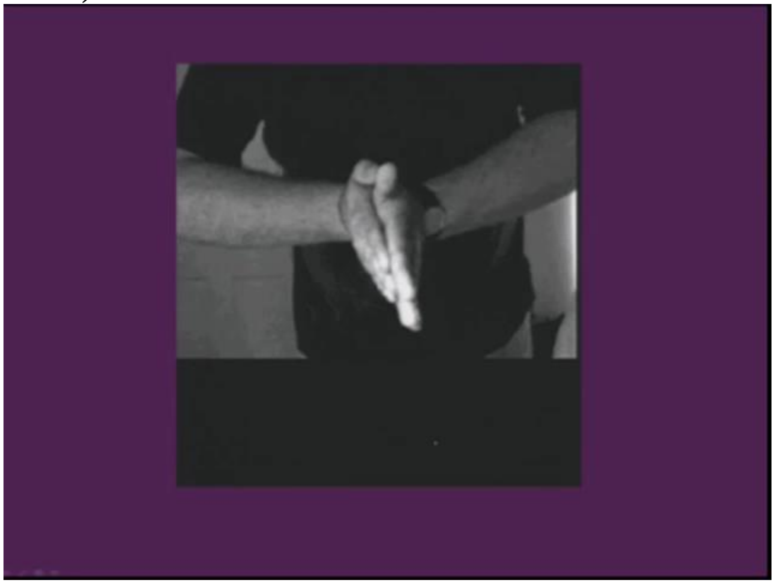

So this is an best example which has been explained in the USDA site that how we can we can look at and try to understand that how earthquakes occur. So if you can take your both the palms and try to press towards each other and try to slip it, so of course you are having friction along this and then sudden release or you can say the slip along this will produce some jerks **in** your hand and those vibrations is your earthquake.

So whenever there is an the pressure is there within the earth's crust when we are talking about the two continental or oceanic continental plates are colliding or subtracting, then you are having the compression which has been developed on either side. And then over the time, the strain will be developed and sudden release of the strain along these weak zones will result in to the vibrations. And that sudden release of the strain is the process what we call the earthquake.

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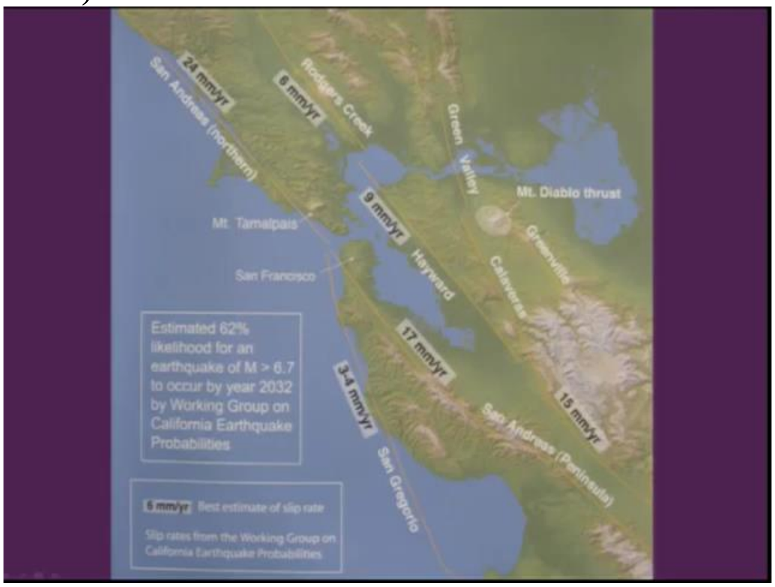

So I will stop here. But I will start with this topic in the next lecture and we will talk more on the earthquakes and the seismic interior of Earth. Thank you so much.