Earthquake Geology: A tool for Seismic Hazard Assessment
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Lecture # 14
Interior of the Earth (Part I)

Welcome back. So, in previous lectures, we have almost discuss some very basic things which are important for the values Seismic for logical studies starting from primary structures, we talk about primary structure secondary structures and how we can differentiate those in field as well as on the surface we have not talked much we will definitely going to discuss more in detail when we are talking about the field mapping as well as the land for mapping using photo geology and high resolution satellite data.

Now, the another important portion, which I feel strongly that we should know is the seismic interior, but basically we are not going to go into so much of detail of seismic interior, but for us, it will be important that what are the different type of seismic waves which are generated during an earthquake and what kind of damage they are going to result in. So, that is basically important and whether we are sitting in in seismically active zone and further narrow down then we are talking about the epicenter zones also we either we are sitting in the epicenter zone.

What sort of effect we will experience and if we are sitting away from the epicenter zone what effect we will be experiencing earlier in the introductory part, I discussed about that this whole exercise is important to reduce the damage and the seismic shaking we will play an important role in towards the damage. So, and the shaking will definitely be controlled by the local geology of any region.

Anyway let us go ahead and have a very quick look at that what are the different type of seismic waves and what are their properties because that will let us know that weather with the help of with the understanding of the seismic wave can we improve or safeguard ourselves and reduce the damage pattern. So, the interior of Earth.

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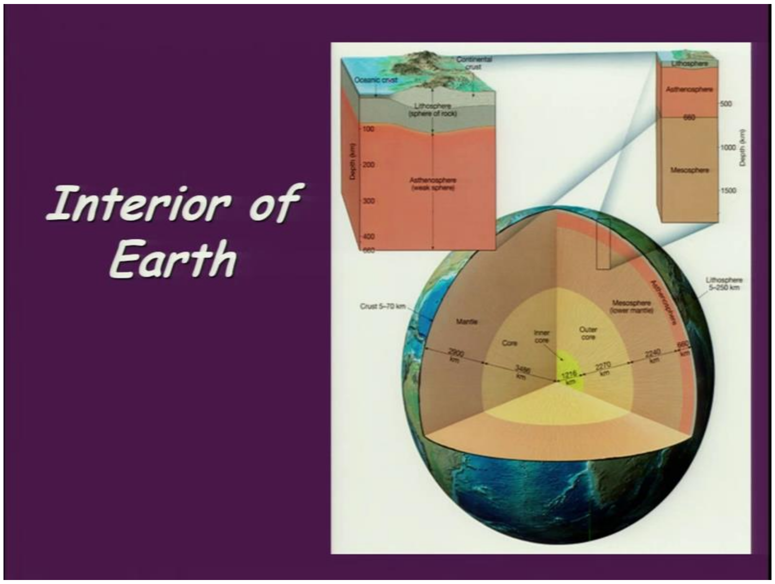

Basically if we go back into the geology then we try we know that the interior of Earth is not homogeneous it is divided or it is high comprised different layers of different density as well as different property. And as we discuss that for us, this layer is important because when we are talking about the plate tectonics, then we discussed about this stenos sphere which is partially molten and is responsible for moving the plates or the movement of the oceanic plate or the Continental plate on the Earth's surface.

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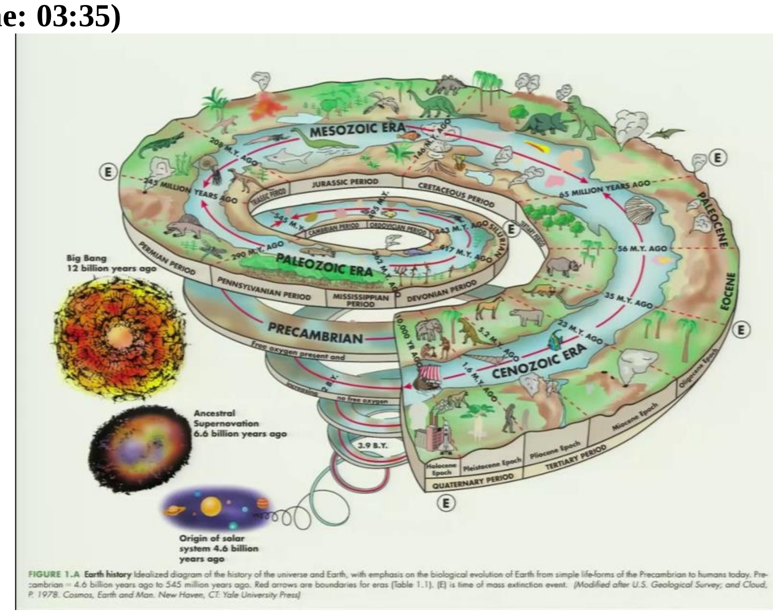

So, going back since the birth of the earth, mostly what we have seen that there were many major events like what we call the supernova or Big Bang, and so similar are not so big but materialistic impacts over the time haploid it important role and in plate tectonics and over also in terms of the segregating the different layers of the interior of Earth. So, this is just 12 years information that the Big Bang was around 12 to 15 billion years back, this explosion produced atomic particles that later from galaxies stars and planets.

Then again at around 7 billion years ago, another explosion that was supernova occurred and the origin of earth or you can say the solar system is as well as like 4.6 billion years.

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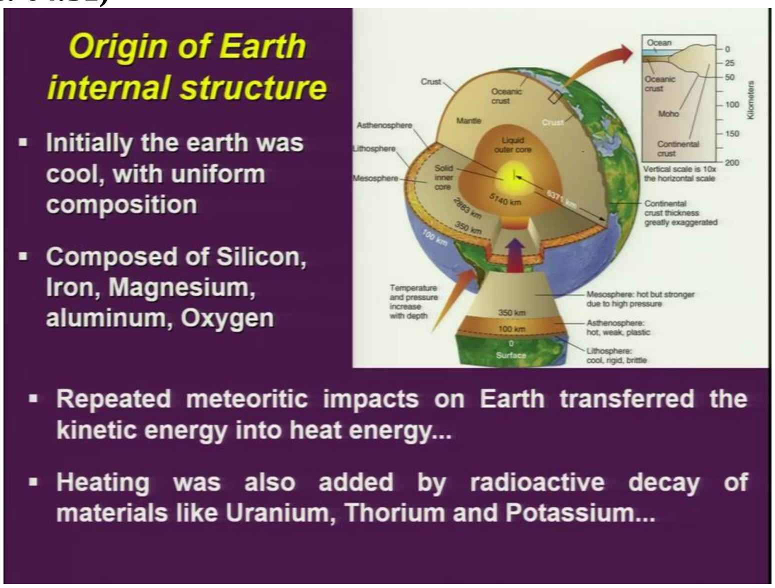

So, origin of internal structure, if we look at then we as we discuss that we do not have we have like, we do not have the homogeneous structures we have and heterogeneity across it, where we have the crust than mantle and cores. So, initially, the earth was is cool with uniform completion composed of silicon, iron, magnesium, aluminum and oxygen. Now repeated meteoritic impacts on earth transferred kinetic energy into heat energy.

So, the heat which is been responsible for the outer core which is liquid and the inner core which is solid is like because of the high pressure in this portion is solid but this is out of this liquid and continuous heat is been produced because of the radioactive decaying of the radioactive material uranium thorium potassium. So, this is one of the major reason for the heat transfer and the liquid as well as in the close to the crust that is based in Western Australia.

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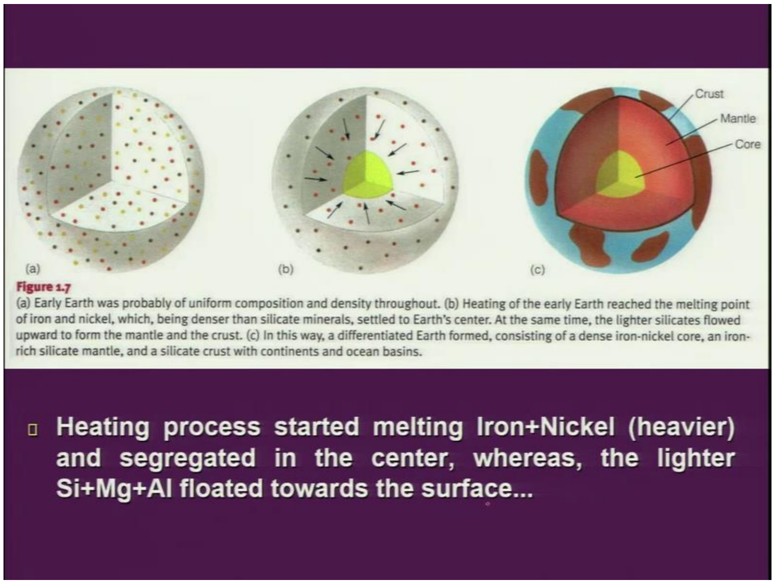

So, they may basically the initial stages, the earth was uniform and served with the uniform density throughout then heating of the early earth reached the melting point of iron and nickel, which being dense then silicate minerals settled to the earth center. So, this melting and this melting was resulted because of the heating and as we discussed in the previous line that the heating was because of the change in the kinetic of kinetic energy due to the heat energy.

So, this was the reason for that and then the main cause, the reason for this and it was the meteoritic impact. So, then, because of it is the iron and nickel were denser as compared to silicate minerals, they settled down into the center of the earth. At the same time the lighter silicate flowed upward from the mental and crust to that to form the mantle and crust. So, this where the lighter material which flowed or move towards, within then towards the upward direction and resulted formation of mental and the crust.

So, in this way differentiated so, this is the others what we see as that the it is not homogeneous or heterogeneous and in the denser material like iron nickel and they are they are sitting in the core area and the lightest ones are sitting on the edge part. So, we have the heavier 1 iron and nickel and in the core and iron rich silicate is your mental and a silicate crust with continents and ocean basins.

So, heating process started melting iron and nickel heavier one and segregated in the center, so they moved to the center where is the light floated towards the surface. Now, this is just for our knowledge and understanding because this is going to help us understanding the propagation of seismic waves through the interior of Earth, this is very will be an important parameter to understand that.

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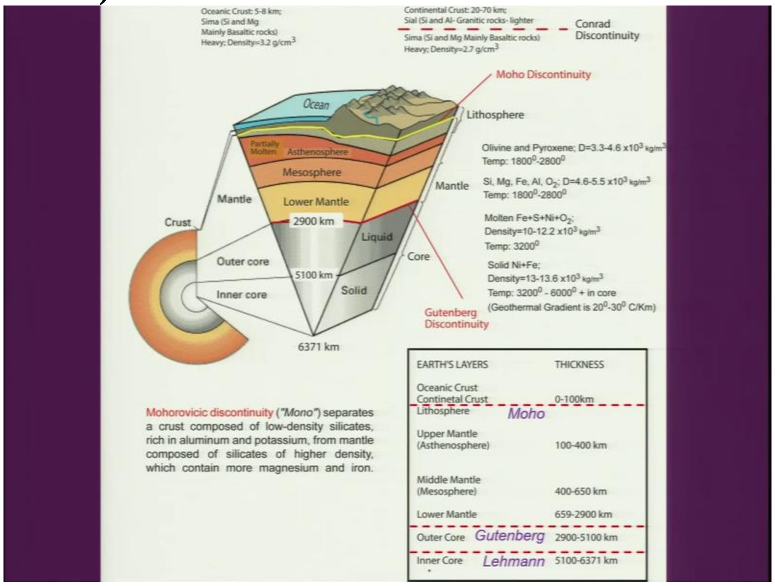

Now coming to this we initially discussed to some extent but of course we can go into further detail. Now, I have tried my best to list down all the composition of the mental and then we have the code and all that but in short you can study this but in short we can what I can tell you right now is that we have the 3 major units here, 1 is the core area another is the mental and then we are talking about the lithosphere here that includes the crust and the upper part of the mental.

So, and if you get into the part of the crust the uppermost portion of the earth, we have oceanic crust and we have continental crust. So, the oceanic crust ranges in thickness up to 5 to 8 kilometers or maximum to 10 kilometers and where will where is this the continental crust is goes up to 20 to 70 kilometers and overall the crust as well as the we can see the lithosphere it goes up to 100 kilometers.

So, we have the upper part of the mantle that is external sphere is from 100 to 400 kilometers middle mantle and so on. And we have the discontinuities between this units and this first discontinuity which has been marked here is termed us more discontinuity was one more discontinuities been seen within the continental crust is it is mark as Conrad discontinuity and between the silica and alumina rich rocks and the heavier ones are the mainly the basaltic 1 which comprised of silica and magnesium.

So, this can discontinuities been termed us Conrad discontinuity, this is Moho discontinuity, that is that separates a crust composed of low density silicates rich in aluminum and potassium from mantle composed of silica silicates of higher density which contains more magnesium and iron. And then further we have the discontinuity between lower mantle and the outer core terms Gutenberg discontinuity.

Now, the density of the material changes the composition changes and because of the change in the density and the competition the seismic waves which travels through the interior of work will behave differently and will have different effect on the surface. So, for us this is important. Now, moving further, we have one more here like Lehmann discontinue that is between outer core and inner core because there is a drastic change between the outer core and the inner core in terms of the density.

And also the competition not exactly the competition, but at least we can say the properties changes because this is outer core is liquid is the inner core is solid.

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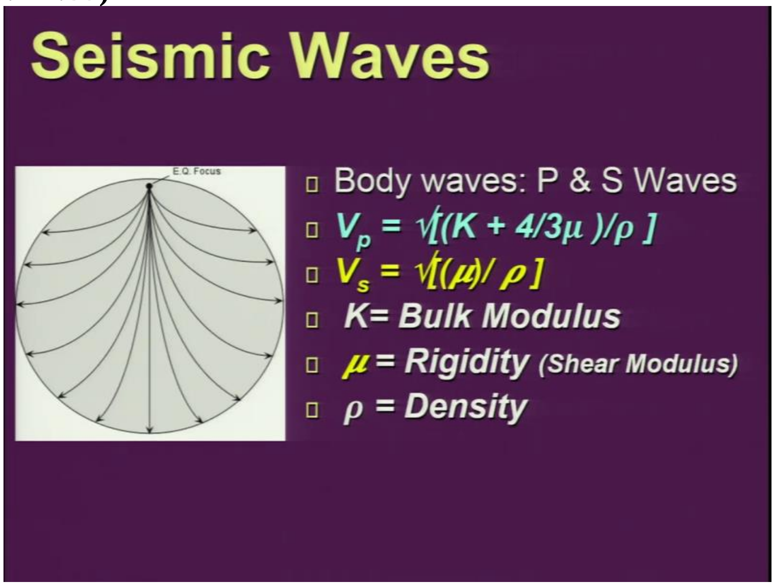

Now, if we consider that the seismic the interior of Earth is homogeneous and if we trigger an earthquake at this point or any point here, so, the waves will travel will propagate like this in this fashion and it will be reached or recorded on the surface around the globe, but this is not true exactly. So, during an earthquake, the 2 type of waves are generated and first if we see the body waves, which comprises the P and S wave primary and secondary waves and the equation which has been given here there is a wave equation.

which talks about where we and this 1 is for here P wave and this 1 is for S wave, wave K is the bulk modulus and new is you are rigidity, shared modulus and rho is the density of the material. So, this is the density of the crust we will take and then modulus of bulk modulus and shear modulus will take. So, this part is like important wave we are talking about shear modulus and all that when we discuss more about the details about the body waves.

Because of its nature like the nature of the respective waves, they will not be able to propagate through all medium because if the medium is different, like it is if solid liquid or gaseous then it will change.

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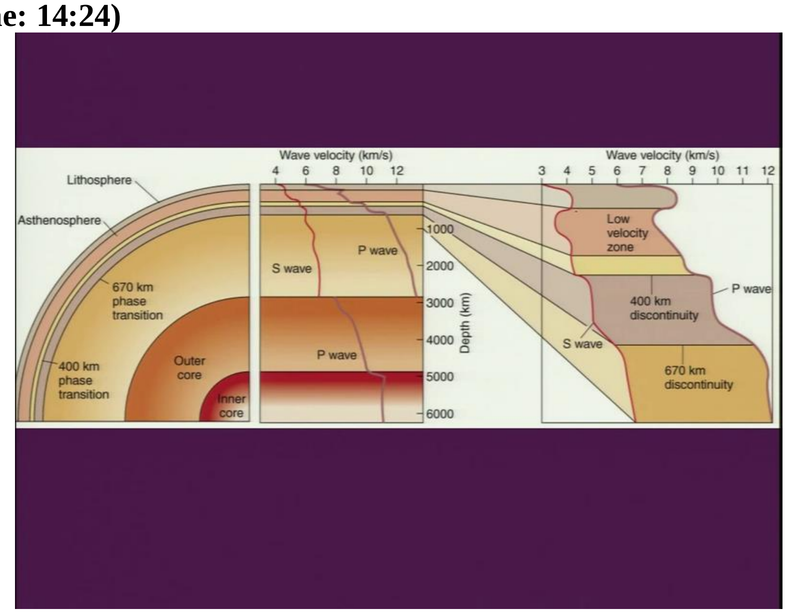

Now, this figure indicates towards that how the seismic waves propagates through the interior of Earth and how their velocity varies as they move through and as they come into the contact between the different 2 layers. So, the so first we have the lithosphere then we have an Asthenosphere. So, that is the part of the crust then we are having this Asthenosphere here and then moving down here there are few fine layers which are been termed or given here but this one then the Asthenosphere.

What we see is considered to be the low velocity zone and then you have the other units over here. So, just within the within almost like 800, 900 kilometers from the crust, we have lot many layers, smaller thickness layers, which shows that the there is a change in the velocity and as you move further down, this is the part of the outer core and then we are having inner core what is happening.

So, what we see as not initially the waves are generated, then in the crust, the velocity of so this is you are S wave, red one and the lighter one is here P wave. So, the S wave travels with a lesser speed whereas the P wave travels with the highest speed here with more than 6.5 kilometers per second and then further it reduces somewhere here and then similarly, you can see that there is some reduction in the velocity of theorem.

And then further gain the velocity and then again slows down and then goes like this and this is the part of what you see the mantle area but this 1, it gains the this the velocity where it increases almost up to 10 to 12 kilometers or here, but then it shoots up here and further, you will not be able to see that it is passing through this reduces and then move out of the interior of the inner core whereas, this 1 you would not be able to see that it is traveling further.

So, the P wave is going through whereas, the S wave is not and this wave will discuss in economics lights. So, just remember that, within the upper 1000 kilometer or 900 kilometers area, we have the low velocity zone and this low velocity zone is your external sphere.

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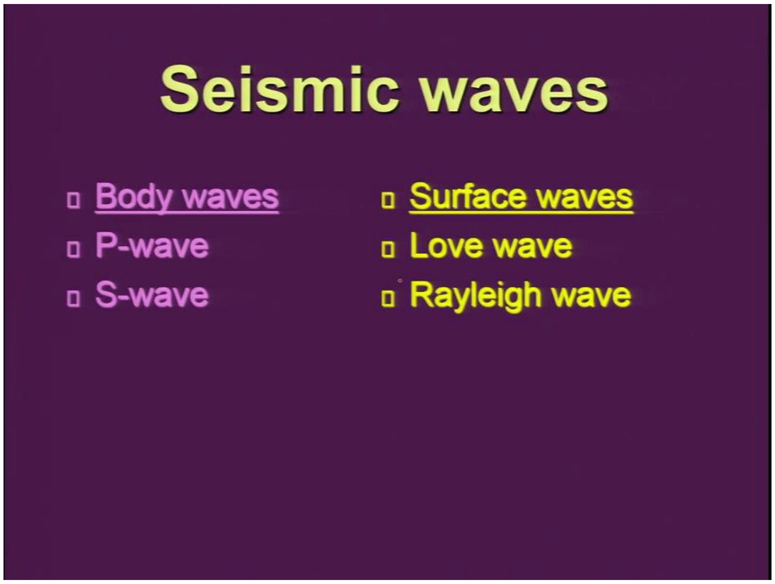

So, seismic waves we have body wave, body wave includes P wave and S waves and then we are having surface wave which had been termed as love wave and Rayleigh wave. So, we will quickly look at that what are the different type of the properties of this different type of waves.

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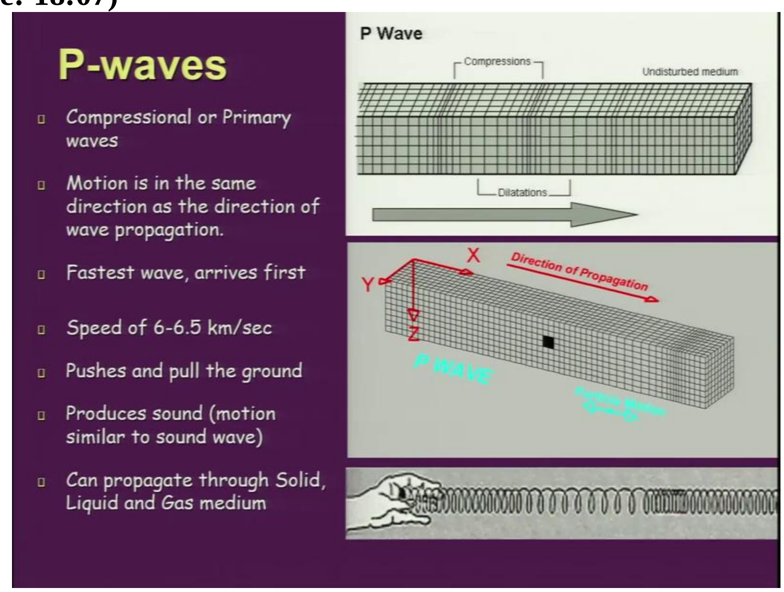

So, P wave are also termed as compressional waves. So, they usually are very much similar to what you go, we have this that like push and pull, if you are doing the taking this spring tide up at 1 end, and then if you push and pull, then what type of the waves are generated that similar waves are you are P waves which are generated at the time of an earthquake. So, P wave if you carefully see the particle what you will be able to see that it is compress and relaxed, compress and relaxed.

So you are having, so, the direction of the propagation is in this direction, and particle is getting compressed as we would talking so, compression and dilation is the basic property of this wave This is also termed as primary waves are that what comes as an P wave. So, it is not primary wave of compressional wave motion is in the same direction as the direction of propagation. Fast, fastest wave arrives first speed is in this is about for the crust.

So, we are having 6 to 6.5 kilometers per second pushes and poles or you can say compress or compression and dilation. So, pushes and pull the ground produces sound because the motion is similar to sound waves. So, if you compare this the motion then this is very much similar to sound wave and that is one of the reason that before the S wave arrives, because S wave is slower as compared to the P wave will arrive first.

So, the P wave when it travels and reaches this surface travels through the interior of earth and reaches the surface it will produce sound. So, the epicenter of regions the areas which are sitting in the epicenter region will the people will experience or will hear the sound before the seismic the that is the S wave arrival before the arrival of this wave. So, this is very important point and then this wave can travel through solid liquid and gas medium. Now, coming to then another one.

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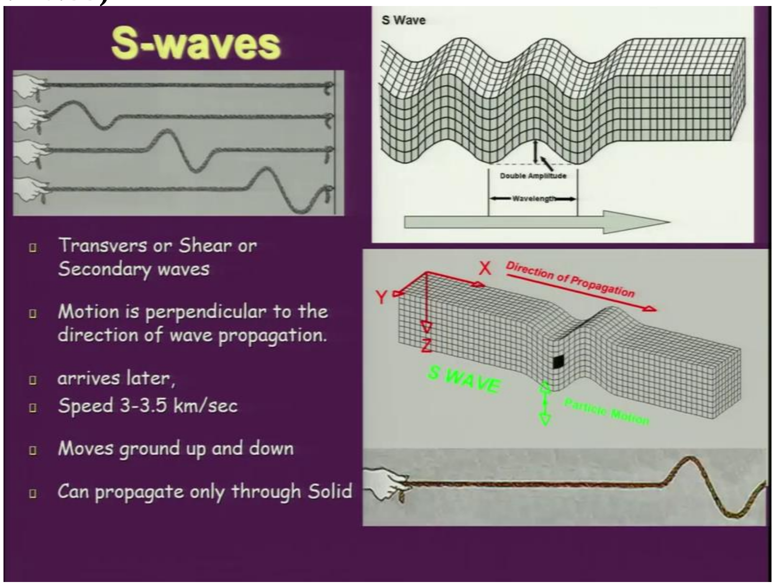

S wave S wave is again a part of the body wave, but it moves up and down. So, the motion is almost what we call perpendicular to the direction of wave propagation and this will move the area up and down. So, if you see carefully the particle here, then you will be able to understand that it moves the particle up and down. So, the motion the previous one was the direction of the motion was in the direction of propagation, here the motion is perpendicular to the direction of propagation.

So, if you want to experiment this you can tie up a rope here at 1 end and try to push up and down and the amplitude which will be generated with will be similar to what you will see in the propagation of the S wave. So, motion is perpendicular to the direction of wave propagation, it is also termed as secondary wave. So, the S comes from the secondary wave or shear wave or transfer wave arrives later the velocities comparatively half in the crust.

So, it is 3 to 3.5 kilometer per second moves the ground up and down can propagate only through solid. Now, this is because then it is the type of propagation which it has, so, then you cannot share the material, if it is liquid so, in a liquid like layers it will not be able to propagate. So, can that is one of the reason that so, it can only propagate through solid.

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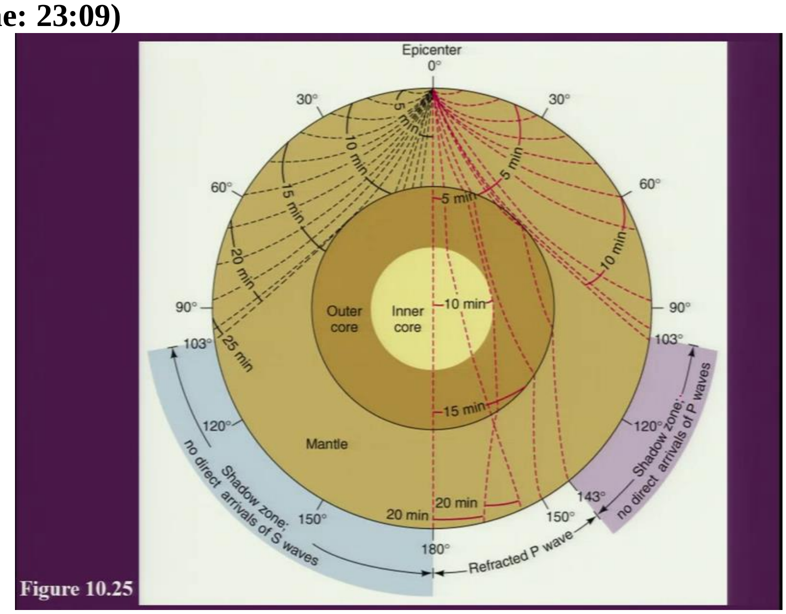

Figure 10.25

And that is one of the reason that you will not be able to record this S wave on the other side of the surface when if the earthquake has been triggered here. Now, this figure at shows that you have the earthquake has been triggered somewhere here for example, at 0 degrees and then the waves travels through the interior of Earth. So, what we see is that we have the S and P waves which will definitely will travel through the interior of earth and then reaches this area.

But further down, you will not be able to see the propagation of particularly the S waves because S waves are not going to travel through the outer core, as we have been talking about here that it can only propagate through solid. So, S waves will not go through the outer core with outer core is liquid. So, you will not be able to record this on the other side of the earth globe because you do not have that because they are not passing through this whereas, the P waves will get refracted.

Because of the reduction in the velocity and also because of the inner core and they will be received in certain areas and this is the region where we will be able to receive the refracted P waves. And since the all P waves are traveling through the inner core and to the periphery of the outer core and the inner core are reflected and see will not be able to receive in this region. So, again this will be what we call is the shadow zone.

Shadow zones are the zone which will not receive any waves. So, either then this is shadow zone of for example, the P wave no direct arrival of P wave has been recorded in this region. Whereas, here you will only have the reflected waves and then this part like for example, you can take mall this region whole region, no problem, either on this side or this side, there is just to give an example.

So, the whole part that is from 180 to 103 or you can say from 182 to 103 here, the whole region, you will see, you will not find or record any S wave. So this will be the shadow zone of S wave. Now, there is no direct arrival of S waves. So, we will stop here, and we will continue in the next lecture.