ENVIRONMENTAL GEOSCIENCES

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Lecture-2

Internal Structure of the Earth

Welcome to the SWAYAM NPTEL course on Environmental Geosciences. In the module 1, today I will discuss the lecture 2 which is internal structure of the earth. So we have already seen in the lecture 1 about the different hypothesis of the origin of the earth. Today we will learn about the internal structure of the earth. In this lecture 2 the important concepts will be covered as the different layers of the earth crust, mantle and core these are the three important layers inside the earth. So here in this lecture 2 we will discuss we will learn about the different parameters different concepts different characteristics of the three important layers.

Now, the first layer is the crust. Just after this crust we are getting the mantle and the bottom most layer is the core. So the study of the structure of the earth actually focusing on this layered structure only and the variation in the density and temperature at various depths because these layers are located at different depths so what are the different types of densities and temperature level revealing this chapter in this chapter we will discuss in greater detail. So earth structure is actually layered one. Each layer is varying in terms of density, temperature, composition as you move deeper. So this is the general variations.

The shape is, the structure of the earth is roughly spheroid in shape. The earth is a globe having a radius of about 6378 km. Sometimes we also see 6371 km. The layered structure of the earth developed during the process of its transformation from a hot gaseous state to the present state. So during these processes, the heavier material sank down and the lighter material floated up and consequently.

So this way the different layers have been formed. Because of the differential densities of the materials constituting the earth's layer, they got separated and formed different different layers with different densities. So this is the reason why having the different layers with different densities different materials different characteristics so in this way

the different layers have been formed inside the earth's surface. Now these layers are broadly divided into three major parts as i have told you crust, mantle and core. So, crust, mantle and core, these are the three important layers. You can see in the diagram also, this is the diagram in which you can see the top portion, the top portion is the crust one, this is the crust one, this is the crust one, top portion is the crust one and just below to the crust is the mantle, is the mantle, just below to the crust is the mantle.

And at the bottom is the core. Here we can see the core is here. The core is here. So crust is at the top part. Then upper mantle comes.

Then lower mantle comes. Then the outer core comes. Then the inner core comes. So in this way different layers of the earth remains inside the earth's surface. Now, in this figure, this is also a figure telling about the different layers.

From seismological, because some evidence is required for knowing about the different layers, so seismological studies suggested that the three segments of the earth, that is crust, mantle and core are separated by two sharp breaks, usually known as discontinuities. So in this figure also you can see up to here to here is the crust. This is the top part just beneath the surface. This is the crust. And just below the crust is the mantle.

Here, up to here is the mantle. And then we are having the core. This is the core. So this is the core, this is the mantle and this is the crust. Now, you can see the

This crust and this mantle and core, between crust and mantle, and between mantle and core is one sharp break, which is generally known as discontinuity. It is known as discontinuity. And the name is also given. When we are getting a sharp break between crust and mantle, then it is known as Mohorovicic discontinuity. Mohorovicic discontinuity.

But when we are getting a sharp break in between the mantle and core, then this is known as Guttenberg-Weichert discontinuity. So in this way, we can learn about this, that between the crust, between the crust and the mantle, if there is a sharp break, then that is sharp break is termed as discontinuity and the first break name is Mohorovicic discontinuity, near about at the depth of 32 or 33 kilometers. And the second break, we are getting, major break, we are getting the Guttenberg-Weichert discontinuity. Guttenberg-Weichert discontinuity. So this Guttenberg-Weichert discontinuity is just separating the mantle with the core.

So the crust is having thickness of about 33 kilometers. So this crust, now, this crust is having thickness of about 33 kilometers. 33 kilometers. The crust is composed of heterogeneous rock. Heterogeneous rock means different types of rocks. Primarily we are having three important types of rocks.

Igneous rock, sedimentary rock and metamorphic rocks. So generally the crust is composed of heterogeneous rocks. And the mantle from the crust, the mantle is extending up to the depth of 2900 km. 2900 km. So, and the third major segment is the core. You can see third major segment is the core, which is extending up to 6371 km, which I have discussed in the previous slide about the radius of the Earth's interior.

So, what we have seen in this slide, that the crust is the topmost portion. Mantle is just beneath the crust, and core is at the bottom of the Earth's interior. Again, we have seen that different layers, these three different layers, are having different densities, different temperatures, etc. So, different characteristics, different types of rock assemblages, etc. In this slide, we can learn about that one sharp break has taken place, which sharp break is generally termed as discontinuity,

And the name is also given, the crust and mantle, sharp break between crust and mantle is the Mohrovicic discontinuity at the depth of 33 km. So the thickness of the crust is near about 33 km. The sharp break between mantle and core is the Guttenberg-Weichert discontinuity. So, this Guttenberg-Weichert discontinuity and the Mohrovicic discontinuity, these are also known as first order discontinuity. They are also called as major discontinuity or first order discontinuity.

But again, in this figure you can see, I will discuss in detail in the later slides also, that in between the upper crust and lower crust, there is again one sharp discontinuity. The sharp break is there. But this is not the first-order discontinuity. This is called a second-order discontinuity. And the name is given as Conrad discontinuity.

And the layer's name is given as Sial and Sima. Sial and Sima. So this is Sial, the, the layer of the crust which is just beneath our Earth's surface is Sial and after that the Conrad discontinuity comes at the depth of about 11 km and then the second layer of the crust is named as Sima. So here we have seen that this crust depth of, the thickness is about 33 kilometer is again separated by some discontinuity named as Conrad discontinuity at the depth of 11 kilometer and then the two different layers evolved and the top just the top at the top is known as Sial and the bottom crust is known as lower crust is known as Sima. So this is clear from the figure.

One more discontinuity we are getting at the depth of about 950 kilometer that is named as Repetti discontinuity, Repetti discontinuity. This discontinuity is separating the the upper mantle with the lower mantle the depth of 950 kilometer we are getting second Repetti discontinuity this is also second order discontinuity. And again here in the bottom you will see the core is also separated in three important layers that is the inner core, outer core and between the middle core. So these are some of the facts about the interiors of the earth, about the different layers, different layers what we are getting crust, mantle and core. So in this way we have learnt the discontinuities also, major discontinuities also. Now, as I have told you, what were the evidence? The seismological studies were the evidence.

So, what type of evidences seismological studies have given? Seismological studies gives evidences regarding the existence of the number of minor discontinuities within the earth, which may be because of changes in the chemical composition of the materials. Changes in the chemical composition of the materials, changes in the density of the materials, changes in the state of a given material, whether it is in solid, liquid or viscous state, and changes in the physical properties of the minerals, etc. So, these are few facts through which the seismological studies also suggested that there are some minor discontinuities in between the different layers of the Earth's interior. Now, One by one, we will discuss these thing, the crust.

As I have shown you the detailed picture of the interiors of the Earth in the previous slides, the crust is the outermost layer of the planet, forming a thin, rigid cell around the Earth's interior. So topmost portion is the crust. This is the crust. It plays a crucial role in the geological processes, supports, life and acts as the foundation for the various ecosystem. So this crust is very much helping in the different types of geological processes rather supporting the life also on the earth's surface and acts as the foundation for the various type of ecosystems what we are getting on the Earth's surface. So the role of the crust is very very important. It is, as I have discussed in the previous slides, that the heterogeneous rock types are present in the crust.

So, it is, the crust is broken into tectonic plates, tectonic plates that float on the semi-fluid asthenosphere. So, one more thing, just I am telling you here, that the crust and the upper mantle, see, we have seen the figure in this way in the previous slides. So, this is the crust. This is the crust, this is the mantle, and this is the core. This figure we have seen in the previous slides.

So, crust we have seen that separated by Mohorovicic discontinuity, and this mantle and core is separated by Guttenberg-Weichert discontinuity. Crust we have seen that the upper crust and lower crust were there. Sial and Sima. Sial and Sima were there. And in the mantle we have seen the different layers. But here also the upper mantle.

This is the upper mantle. And this is the lower mantle. Okay. So upper mantle and total crust. If you will combine then this will become the lithosphere. This is called as lithosphere.

So crust. Total crust. Sial, Sima. Total crust plus upper mantle, combinedly called as lithosphere and just below the lithosphere zone is known as the asthenosphere. So this is the asthenosphere, this is the asthenosphere. So the crust plus mantle, upper mantle is called as lithosphere and just below it is called the asthenosphere. And this lithosphere, this lithosphere, is composed of different different types of rocks this is composed of different different type of rocks and these rocks generally form the plates. That's why this crust is made of, it is broken into tectonic plates and these plates because these are the hard material it can able to float on this semi fluid asthenosphere. It is not hard it is semi fluid stage, so this hard portion is will float on this asthenosphere because this portion, this portion is not hard portion, this is in the semi-fluid stage.

So causing, that's why the plates, means the rocks of the lithosphere is just moving on the asthenosphere, that's why we are getting the earthquakes and volcanic activities on the Earth's surface. This is the important reason why we are getting earthquakes and volcanic activities. Because these, these, are earthquakes and volcanic activities are related with the movement of the tectonic plates. And tectonic plates are nothing but these are the hard rocks which has composed the lithosphere, not only the crust but the lithosphere. So lithospheric plates are also known as tectonic plates.

So now this crust if you will see we are concentrating on the crust portion in this slide. So this crust is basically divided into two parts that is on the basis of structure of the crust. First the crust, crustal portion on the continent is known as continental crust whereas crustal portion in the ocean is known as the oceanic crust. So this crust is of two types continental crust and oceanic crust. Now, continental crust is thicker. As I have told, continental crust will remain in the continent portion of the globe. So it is thicker, averaging about 55 to 70 kilometers, but less dense. Composed mostly of granite. Granite is an igneous rock, is an igneous rock and other less dense minerals. So this

continental crust forms the land masses and contains the oldest rocks on the Earth, some rocks is up to 4 billion years old also.

So this continental crust is thicker whereas oceanic crust is thinner one about 5 to 10 kilometer only and this is denser the continental crust was less denser but it is denser primarily composed of basalts and gabbro that continental crust is composed of mostly of granite but it is composed of basalt and gabbro. It, these are also rocks. It underlies ocean basins and is much younger than the continental crust. It is just lying in the ocean basin and is younger than the continental crust also with rocks usually less than 200 million years old due to the continuous recycling at tectonic boundaries. So these are the two different types of crust on the basis of the structure that is continental crust and oceanic crust. This crust, as I have discussed in the previous slides also, is subdivided into two layers, again on the basis of some chemical composition, that Sial the upper portion, as I have discussed in the previous slide also.

See, this is the, your crust, just I am taking the crust portion. So this is the crust. So here you can see, this is the upper crust, Upper crust, this is the lower crust. Upper crust was named as Sial, whereas lower crust was named as Sima.

We have seen also. This is the discontinuity, Mohorovicic discontinuity. So now I am discussing or concentrating on this portion only, Sial only. So Sial is derived from two words, that is silica and aluminium. So the two predominant elements in this layer.

Minerals, now based on the minerals. See important minerals of this sial is feldspar and quartz these are important minerals and it is giving the granitic composition that's why we have seen the granite was much more abundant in the continental crust so here you can see the silica and alumina these two are the predominant elements remains in the Sial layers. This layer is found predominantly in the continental regions and forms the bulk of the continental crust. I have discussed already this thing. Density, I have told you the continental crust is less dense compared to the oceanic crust.

Oceanic crust will be denser. So density, it is less dense than the underlying Sima layer with an average density of around 2.7 gm/cm^3. Thickness, Sial is generally thicker, especially in the mountainous region, averaging around 20 to 70 km, because we have seen the average thickness of the crust on the continent is about 33 km, in the ocean is near about 5 to 10 km. But in the mountainous region, generally the thickness of the crust increases near about 50 to 70 km. So Sial is generally thicker, especially in the mountainous regions, averaging around 20 to 70 km.

And we have seen in the previous slide also that in between the Sial and Sima, one second order discontinuity was there, named as Conrad discontinuity, which is remaining at the depth of 11 km. So this Sial layer just separating from the underlying Sima layer by one second order discontinuity and it is located at the 11 km of depth named as Conrad discontinuity. So this is about the Sial layer of the crust. Next is the Sima. So Sima, here again the word combines the two predominant elements that is silica and magnesium.

So this layer is rich in minerals like pyroxene, olivine. So in this way giving it a basaltic composition. There it was giving the granitic composition in the Sial. Here in the Sima, we are seeing the basaltic composition. So Sima is found beneath both oceanic and continental crust, but is most prominent in the oceanic crust.

This Sima generally we are seeing in prominent in the oceanic crust. Density, I have told you earlier also, it is high density. Then sial, averaging around 3.0 to 3.3 gm/cm^3. Thickness is about 22 km because we have seen in the previous slides that this is, if this is the crust, only the crust portion I am showing you, this is the Sial and this is the Sima. So at the depth of 11 kilometer we were getting one second order discontinuity known as Conrad, Conrad discontinuity.

So this thickness of Sial is 11 kilometer but thickness of Sima is 22 kilometer because we were getting one first order discontinuity named as Mohorovicic discontinuity which is just separating the underlying mantle with the crust. So the depth of the Sima is 22 kilometer. This is very important because what are the depth, depth of the your, your different layers of the crust. So in this way we have seen that the Sima is the bottom layer of the crust and thickness is about 22 kilometer again the Sima is divided into two parts again this Sima is divided into two parts outer Sima this is outer Sima and this is inner Sima Now question comes, how from the depth is what will remain the depth, depth outer Sima this is the 19 kilometer from from 11 kilometer to 19 kilometer is the outer Sima and from 19 kilometer to 33 kilometer is the because this is at the rate of 33 kilometer is the your inner Sima.

So this is the different concepts about the different layers of the Sima that is the lower part of the crust outer Sima extends up to a depth of 19 kilometers. Comprises of rock of intermediate composition and inner Sima located from the 19 kilometers to 33 kilometer. The rock composition is basic to ultra basic in composition. So this is the facts about the crustal portion of our interior of the Earth. In brief suppose you wish to know about the details about the till now so what we have discussed we have discussed the Earth's

interior is majorly having three layers that is crust, mantle and core. Crust is of two types the continental crust and oceanic crust. Again the crust remains of different thickness at different places on the continent.

The thickness is 33 km. In the ocean, it is 5 to 7 km or 5 to 10 km. And in the mountainous region, its thickness varies from 50 to 70 km. So again, crust is divided into two parts, sial and sima. Sial and Sima is divided at the depth of 11 km by one second-order discontinuity known as Conrad discontinuity.

Again, this Sima is divided into two portions. That is outer sima and inner sima. Outer sima extends up to the depth of 11 km to 19 km. Whereas, inner sima depth is from 19 km to 33 km. So, this is the facts about the Sial and Sima. Now, the second major layer known as mantle. So, first we have understood already about the crust. Second layer is the mantle. It is separated, as we have seen in the previous slide also, it is separated from the first order discontinuity, that is the Mohorovicic discontinuity.

Crust is separated by Mohorovicic discontinuity. The thickness of mantle is about 2900 km, we have seen in the figure also. It forms 83 % of the earth by volume and 68 % by mass. So generally, this is the volume and percentage mass of the mantle 83 % of the earth by volume and 68 % by mass and the function the mantle plays a critical role in plate tectonics. Very very important role. Convection currents within the mantle caused by heat transfer drive the movement of tectonic plates. Actually it is just giving the movement of the tectonic plates mantle portion is actually giving the movement of the tectonic plates contributing to phenomenon like earthquakes, volcanic activity, and mountain formation, mountain building formation, orogeny, generally called as orogeny.

So see, I have told you that plates are nothing but these are the rocks of the lithosphere. And lithosphere is nothing but it is just the crust plus upper mantle is called as lithosphere. Since lithosphere is composed of different plates, means hard rocks, so it will always move upon some semi fluid material otherwise it won't move and the semi fluid material is the asthenosphere which is lying just below the lithosphere. Means after the portion of the upper mantle whatever core layers remains of the mantle is the your asthenosphere so since asthenosphere is semi-fluid, so the top portion that is the lithosphere, that is the hard rock, that is the plates all are moving and they are causing, they are responsible for the phenomenon like earthquake, volcanic activity, mountain building etc on the Earth's surface. So this is the facts about the movement of the tectonic plates. Now composition

wise if you see this mantle is composed of silicate rocks generally which rocks which are rich in iron and magnesium.

Common silicates found in the mantle include olivine, garnet, pyroxene. These are the common silicates minerals which are generally we are getting in the mantle that is the olivine, garnet and pyroxene. Temperature ranges from about 500°C near to the crust to around 4000°C closer to the core. So this is the facts about the mantle. Here, you can just see in this diagram also, Conrad discontinuity, then Mohorovicic discontinuity.

Again, the depth-wise discontinuities in layers of the Earth has been shown. Depth-wise, it's clear that at the depth of 290 km, we are getting the Guttenberg-Weichert discontinuity. This we have seen already. This Mohorovicic discontinuity is near about 33 km. It is near about 33 km. So, in this way, we are just seeing the radius of the Earth is 6370 km.

So, this mantle, this mantle, mantle starts from Mohorovicic, after Mohorovicic, to this, you can see here. Upper mantle and lower mantle so this upper mantle and lower mantle is divided by one discontinuity which is known as Repetti discontinuity at the depth of about 950 km. The Repetti discontinuity is a boundary within the Earth's interior. Especially within the mantle. It separates the upper mantle from the lower mantle, this is just Repetti discontinuity. It is just separating the upper mantle with the lower mantle. And in this way, the upper layer of the mantle includes the lithosphere and the asthenosphere. I have discussed already in the previous slides that lithosphere is nothing but it is the crust and uppermost mantle, rigid part of the mantle, which extends down to about 100 kilometers beneath the surface and asthenosphere is directly beneath the lithosphere. The asthenosphere is highly viscous, ductile region, that's why the rocks are moving on it. Where rocks are close to melting, extending from roughly 100 to 200 kilometers deep, the astronosphere semi-fluid nature allows the lithosphere to move.

And that's why the lithospheric plates are moving. That's why we are getting the earthquake and volcanic activity, mountain building activity on the Earth surface. Lower mantle extends from roughly 660 km to 2900 km below the Earth's surface. The lower mantle is under steam pressure. This layer acts as a convective heat reservoir with slow-moving convection currents that help transfer heat from the core toward the surface, driving tectonic activity over long time scales. So this is about the lower mantle.

Now the third layer of the Earth's interior is very well known is the Earth's core. Earth's core is the innermost layer of our planet, which is separated from the mantle by

Guttenberg-Weichert discontinuity. I have discussed in the previous slides also. So Mohorovicic discontinuity and Guttenberg-Weichert discontinuity, these are the first-order discontinuity, major discontinuity, major portion for just separating crust and mantle, if it is separating, it is separating by the Mohorovicic discontinuity. Mantle and core, it is separating by the discontinuity that is Guttenberg-Weichert discontinuity.

So, it plays a crucial role in Earth's geology and magnetic field. The central temperature is estimated to be 6000°C in the core. The central pressure is near about 392×10^8 bars in C.G.S units. Density at the core, at the center is 118 gm/cm^3. And this core layer is primarily composed of iron and nickel.

So what we have seen, this again core is divided into two parts. That is outer core and inner core. So this outer core and inner core. Now just concentrating to the core. Core, this is the core portion. So this is near about 6371 kilometer. So this core is again outer core and inner core. Inner core. So this outer core and inner core is again separated by one second order discontinuity known as Lehmann discontinuity. This is known as Lehmann discontinuity. Lehmann discontinuity.

So this Lehmann discontinuity is a boundary within the Earth's interior that separates the outer core from the inner core. It lies at a depth of 5150 km beneath the Earth's surface. Near about 5150 km beneath the Earth's surface. The discovery of this discontinuity helped scientists to confirm that the Earth has a solid inner core and liquid outer core. So, inner solid core and liquid outer core, this has been confirmed by the presence of this Lehmann discontinuity.

So, in this way, the outer core composition is generally liquid iron and nickel with lighter elements such as sulfur and oxygen, thickness about 2200 kilometers. Characteristic, the outer core is responsible for generating Earth's magnetic field through the dynamo effect. The movement of the liquid iron generates electric currents, which in turn produce the magnetic fields. Whereas the characteristics of the inner core is the, it is mainly composed of solid iron and nickel. Thickness is approximately 1200 kilometers in radius.

Characteristics the inner core is under immense pressure which keeps it solid despite the high temperature that exceed those on the surface of the Sun. The solidification of the inner core is thought to be a slow process related to the cooling of the Earth. So just summarizing the lecture two, you can see here the outermost layer of the earth is called as crust. This crust is of two types, continental crust, oceanic crust. And this crust is again

divided into two layers, Sial and Sima. Second layer is the mantle. Mantle thickness is near about 2865 kilometers because it is extending up to 2900 kilometers.

It plays a critical role in plate tectonics, upper mantle and lower mantle, the two different layers. Core is again the innermost layer of the Earth's crucial role in Earth's geology and magnetic field, playing a very, very important role, and composed of iron and nickel, outer core, inner core. So, this through this diagram also we have seen in the previous slides also that up to 33 kilometer is the crust from 33 to 2900 kilometer is the mantle but the thickness of the crust is 33 kilometer whereas thickness of the mantle is 2865 kilometer because if you will just deduct the 33 kilometer from 2900 that will be the thickness of the mantle. So, in this way we have seen that this crust and mantle is divided by the first order discontinuity that is the Mohorovicic discontinuity, Mohorovicic discontinuity, whereas mantle and core is subdivided into two parts by the Guttenberg-Weichert discontinuity. These two are the first order discontinuity, remaining all whatever we have learnt till now, Conrad discontinuity in the crust separating Sial and Sima, Repetti discontinuity at depth of 950 km in the mantle, And the Lehmann discontinuity in the, your core, that is in the core layer.

So, these all are the second order discontinuity. So, these are all about the internal structure of the earth and the discontinuities present in the Earth's layer. Thank you very much to all.