1. Details of Module and its structure

Module Detail	
Subject Name	Geography
Course Name	Geography 01 (Class XI, Semester - 1)
Module Name/Title	Interior structure of Earth– Part 1
Module Id	kegy_10301
Pre-requisites	Basic knowledge about Interior structure of the Earth
Objectives	After going through this Module, the learners will be able to: • Discuss the Seismic activity of Earth • Describe the Earthquake • Explain the Interior structure of Earth
Keywords	Earth's interior, Earthquake, Seismic waves, Structure of the earth, Crust of the earth, Mantle of the earth, Asthenosphere, Core of the earth

2. Development Team

Role	Name	Affiliation
National MOOC Coordinator (NMC)	Prof. Amarendra P. Behera	CIET, NCERT, New Delhi
Program Coordinator	Dr. Mohd. Mamur Ali	CIET, NCERT, New Delhi
Course Coordinator (CC) / PI	Prof. Aparna Pandey	DESS, NCERT, New Delhi
Course Co-Coordinator / Co-PI	Dr. Archana	CIET, NCERT, New Delhi
Subject Matter Expert (SME)	Ms. Kulwant Kaur	DEEP Public School, New Delhi
Review Team	Dr. V. A.V. Raman	Saheed Bhagat Singh College, Delhi University, Delhi

Table of Contents :

Introduction

Although Earthquakes can have catastrophic effects, they can also reveal a great deal about the earth's internal structure. The shock waves arising from earthquakes pass through the interior of the earth in different ways and provide the evidence about the inaccessible interior regions of earth. The configuration of the surface of the earth is largely a product of the processes operating in the interior of the earth. Exogenic as well as endogenic processes are constantly shaping the landscape. A proper understanding of the physiographic character of a region remains incomplete if the effects of endogenic processes are ignored. Human life is largely influenced by the physiography of the region. Therefore, it is necessary that one gets acquainted with the forces that influence landscape development. To understand why the earth shakes or how a tsunami wave is generated, it is necessary that we know certain details of the interior of the earth. Earth-forming materials have been distributed in the form of layers from the crust to the core. It is interesting to know how scientists have gathered information about these layers and what are the characteristics of each of these layers? This is exactly what this chapter deals with.

Sources of information about the interior

The earth's radius is 6,370 km. No one can reach the centre of the earth and make observations or collect samples of the material. Under such conditions, you may wonder how scientists tell us about the earth's interior and the type of materials that exist at such depths. Most of our knowledge about the interior of the earth is largely based on estimates and inferences. Yet, a part of the information is obtained through direct observations and analysis of materials.

Direct Sources

The most easily available solid earth material is the surface rock or the rocks we get from mining areas. Gold mines in South Africa are as deep as 3 - 4 km. Going beyond this depth is not possible as it is very hot at this depth. Besides mining, scientists have taken up a number of projects to penetrate deeper depths to explore the conditions in the crustal portions. Scientists world over are working on two major projects such as "Deep Ocean Drilling Project" and "Integrated Ocean Drilling Project". The deepest drill at Kola, in Arctic Ocean, has so far reached a depth of 12 km. This and many deep drilling projects have provided large volume of information through the analysis of materials collected at different depths.

Volcanic eruption forms another source of obtaining direct information. As and when the molten material (magma) is thrown onto the surface of the earth, during volcanic eruption it becomes available for laboratory analysis. However, it is difficult to ascertain the depth of the source of such magma.

Indirect Sources

Analysis of properties of matter indirectly provides information about the interior. We know through the mining activity that temperature and pressure increase with increasing distance from the surface towards the interior in deeper depths, Moreover, it is also known that the density of the material also increases with depth. It is possible to find the rate of change of these characteristics. Knowing the total thickness of the earth, scientists have estimated the values of temperature, pressure and the density of materials at different depths.

Another source of information is the meteors that at times reach the earth. However, it may be noted that the material that becomes available for analysis from meteors, is not from the interior of the earth. The material and the structure observed in the meteors are similar to that of the earth. They are solid bodies developed out of materials same as, or similar to, our planet. Hence, this becomes yet another source of information about the interior of the earth.

The other indirect sources include gravitation, magnetic field, and seismic activity.The gravitation force (g) is not the same at different latitudes on the surface. It is greater near the poles and less at the equator. This is because of the distance from the centre at the equator being greater than that at the poles. The gravity values also differ according to the mass of material. The uneven distribution of mass of material within the earth influences this value. The reading of the gravity at different places is influenced by many other factors. These readings differ from the expected values. Such a difference is called gravity anomaly. Gravity anomalies give us information about the distribution of mass of the material in the crust of the earth. Magnetic surveys also provide information about the distribution of magnetic materials in the crustal portion, and thus, provide information about the distribution of materials in this part. Seismic activity is one of the most important sources of information about the interior of the earth

Earthquake

The study of seismic waves provides a complete picture of the layered interior. An earthquake in simple words is shaking of the earth. It is a natural event. It is caused due to release of energy that generates waves that travel in all directions.

The release of energy occurs along a fault. A fault is a sharp break in the crustal rocks. Rocks along a fault tend to move in opposite directions. As the overlying rock strata press them, the friction locks them together. However, their tendency to move apart at some point of time overcomes the friction. As a result, the blocks get deformed and eventually, they slide past one another abruptly. This causes a release of energy, and the energy waves travel in all directions. The point where the energy is released is called the focus of an earthquake, alternatively, it is called the hypocentre. The energy waves travelling in different directions reach the surface. The point on the surface, nearest to the focus, is called epicentre (Figure 1). It is the point where the waves reaches first and this point is directly above and nearest to the focus.

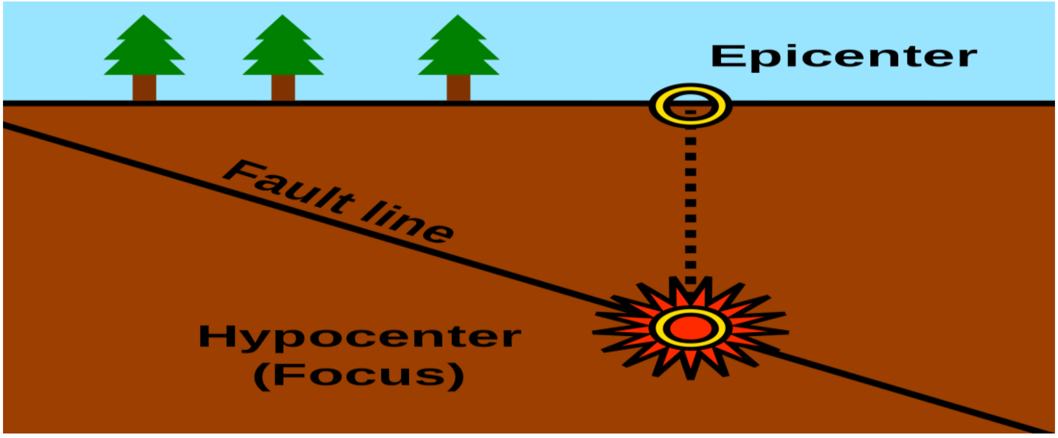

Fig No 01: Focus and Epicentre

Source:https://upload.wikimedia.org/wikipedia/commons/thumb/a/a3/Epicenter_Diagram.svg/2000px-Epicenter_Diagram.svg.png

Earthquake waves

All natural earthquakes take place in the lithosphere. Lithosphere is a solid rock layer around the earth from the surface into interior. You will learn about different layers of the *earth later in this module. It is sufficient to note here that the lithosphere refers to the portion of depth up to 200 km from the surface of the earth. An instrument called 'seismograph' records the waves reaching the surface.*

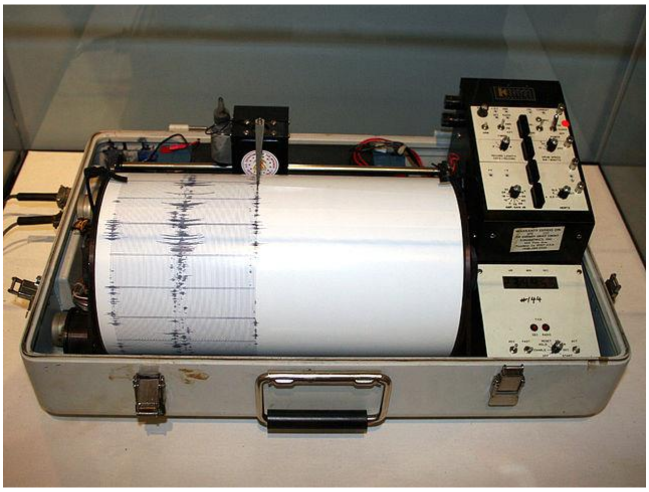

Fig. No 02: Seismograph

Source:https://upload.wikimedia.org/wikipedia/commons/thumb/0/0f/Kinemetrics_seismograph.jpg/320px-Kinemetrics_seismograph.jpg

A curve of earthquake waves recorded on the seismograph. Earthquake waves are basically of two types — body waves and surface waves. Body waves are generated due to the release of energy at the focus and move in all directions travelling through the body of the earth. Hence, the name body waves. The body waves interact with the surface rocks and generate new set of waves called surface waves. These waves move along the surface. The velocity of waves changes as they travel through materials with different densities. The denser the material, the higher is the velocity. Their direction also changes as they reflect or refract when coming across materials with different densities.

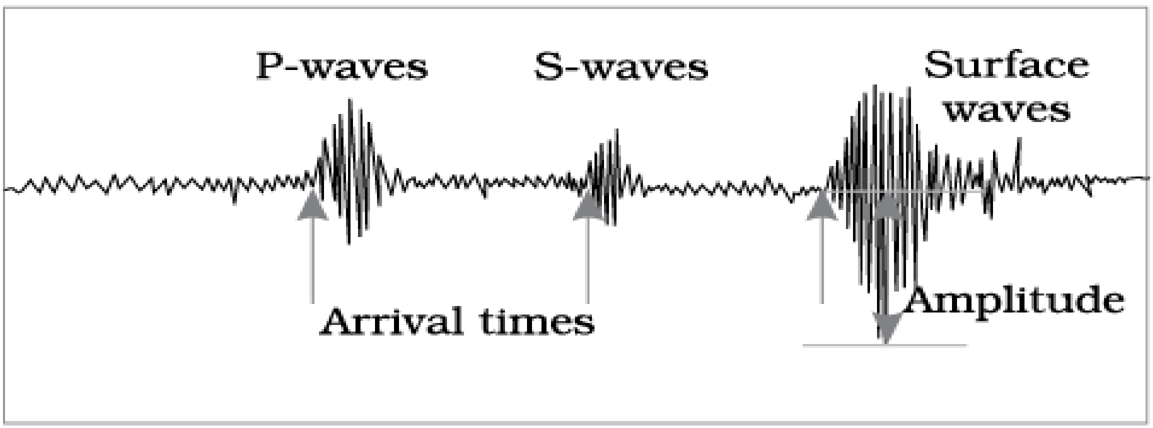

Fig. No. 03 Earthquake Waves

There are two types of body waves. They are called P and S-waves. P-waves move faster and are the first to arrive at the surface. These are also called ‘primary waves’. The P-waves are similar to sound waves. They travel through gaseous, liquid and solid materials. S-waves arrive at the surface with some time lag. These are called secondary waves. An important fact about S-waves is that they can travel only through solid materials. This characteristic of the S-waves is quite important. It has helped scientists to understand the structure of the interior of the earth. Reflection causes waves to rebound whereas refraction makes waves move in different directions. The variations in the direction of waves are inferred with the help of their record on seismograph. The surface waves are the last to report on seismograph. These waves are more destructive. They cause displacement of rocks, and hence, the collapse of structures occurs.

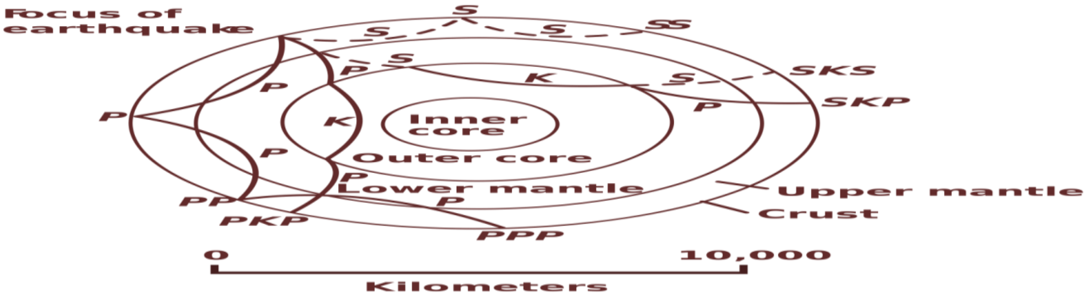

Fig. No. 04 Cross section of the whole Earth, showing the complexity of paths of earthquake waves.

The paths curve because the different rock types found at different depths change the speed at which the waves travel. Solid lines marked P are compressional waves; dashed lines marked S are shear waves. S waves do not travel through the core but may be converted to compressional waves (marked K) on entering the core (PKP, SKS). Waves may be reflected at the surface (PP, PPP, SS). Seismographs detect the various types of waves. Analysis of such records reveals structures within the Earth

Source:https://upload.wikimedia.org/wikipedia/commons/thumb/c/c8/Earthquake_wave_paths.svg/2000px-Earthquake_wave_paths.svg.png

Propagation of earthquake waves

Different types of earthquake waves travel in different manners. As they move or propagate, they cause vibration in the body of the rocks through which they pass. P-waves vibrate parallel to the direction of the wave. This exerts pressure on the material in the direction of the propagation. As a result, it creates density differences in the material leading to stretching and squeezing of the material. Other three waves vibrate perpendicular to the direction of propagation. The direction of vibrations of S-waves is perpendicular to the wave direction in the vertical plane. Hence, they create troughs and crests in the material through which they pass. Surface waves are considered to be the most damaging waves.

Emergence of shadow zone

Earthquake waves get recorded in seismographs located at far off locations. However, there exist some specific areas where the waves are not reported. Such a zone is called the 'shadow zone'. The study of different events reveals that for each earthquake, there exists an altogether different shadow zone.

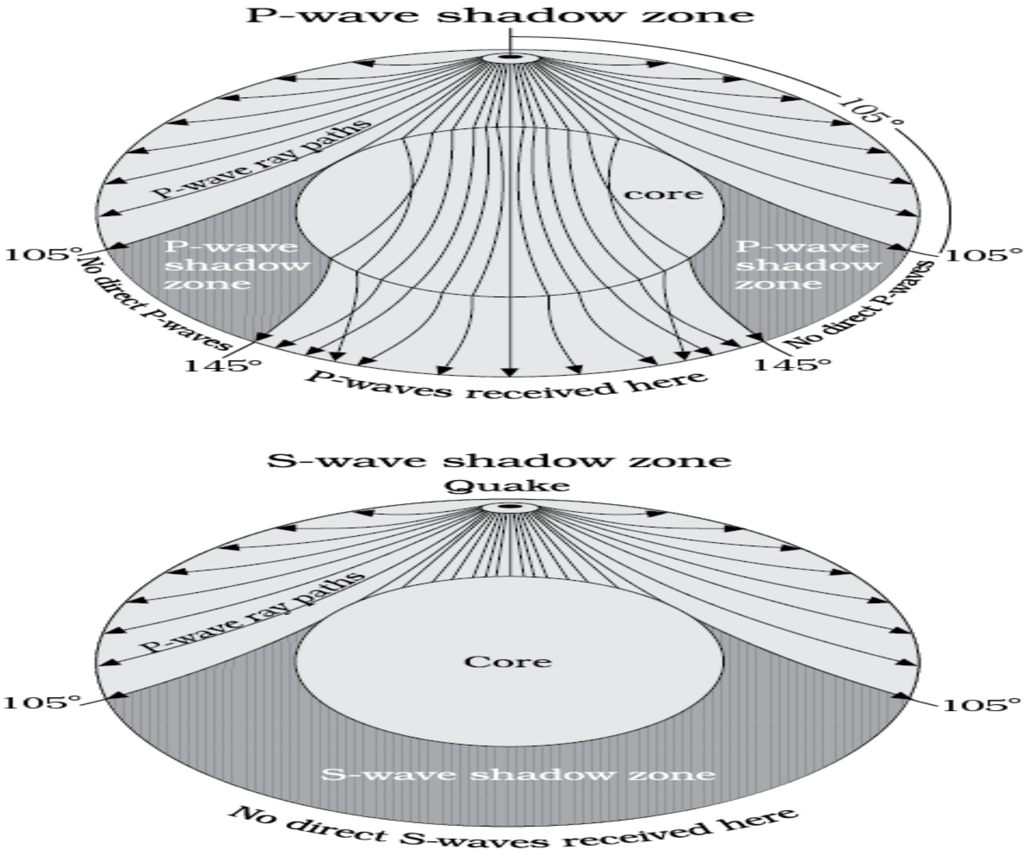

Fig. No. 05 Earthquake Shadow Zones

Above figure (a) and (b) show the shadow zones of P and S-waves. It was observed that seismographs located at any distance within 105° from the epicentre, recorded the arrival of both P and S-waves. However, the seismographs located beyond 145° from epicentre, record the arrival of P-waves, but not that of S-waves. Thus, a zone between 105° and 145° from epicentre was identified as the shadow zone for both the types of waves. The entire zone beyond 105° does not receive S-waves. The shadow zone of S-wave is much larger than that of the P-waves. The shadow zone of P-waves appears as a band around the earth between 105° and 145° away from the epicentre. The shadow zone of S-waves is not only larger in extent but it is also a little over 40 per cent of the earth surface.

Types of earthquakes

We studied earlier in this module, how earthquake occurs and the ways in which the seismic waves gets generated and recorded in a seismograph. The earthquake occurs due to various causes and the same can be classified as under:

i. The most common ones are the tectonic earthquakes. These are generated due to sliding of rocks along a fault plane.
ii. A special class of tectonic earthquake is sometimes recognised as volcanic earthquake. However, these are confined to areas of active volcanoes.
iii. In the areas of intense mining activity, sometimes the roofs of underground mines collapse causing minor tremors. These are called collapse earthquakes.
iv. Ground shaking may also occur due to the explosion of chemical or nuclear devices. Such tremors are called explosion earthquakes.
v. The earthquakes that occur in the areas of large reservoirs are referred to as reservoir induced earthquakes.

Measuring earthquakes

The earthquake events are scaled either according to the magnitude or intensity of the shock. The magnitude scale is known as the Richter scale. The magnitude relates to the energy released during the quake. The magnitude is expressed in absolute numbers, 0-10. The intensity scale is named after Mercalli, an Italian seismologist. The intensity scale takes into account the visible damage caused by the event. The range of intensity scale is from 1-12.

Effects of earthquake

Earthquake is a natural hazard. The following are the immediate hazardous effects of earthquake: (i) Ground Shaking (ii) Differential ground settlement (iii) Land and mud slides (iv) Soil liquefaction (v) Ground lurching (vi) Avalanches (vii) Ground displacement (viii) Floods from dam and levee failures (ix) Fires (x) Structural collapse (xi) Falling objects (xii) Tsunami

The first six listed above have some bearings upon landforms, while others may be considered the effects causing immediate concern to the life and properties of people in the region. The effect of tsunami would occur only if the epicentre of the tremor is below oceanic waters and the magnitude is sufficiently high. Tsunamis are waves generated by the tremors and not an earthquake in itself. Though the actual quake activity lasts for a few seconds, its effects are devastating provided the magnitude of the quake is more than 5 on the Richter scale.

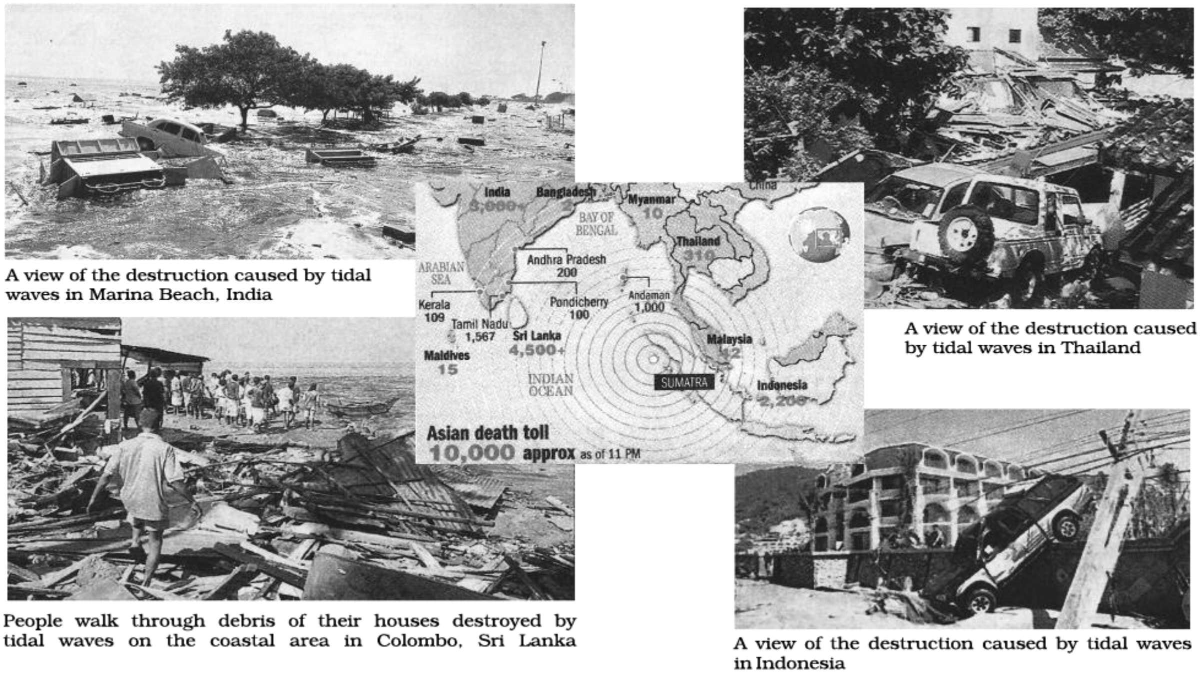

Fig. No. 06 Effects of Earthquake

Fig. No. 07 Effects of Earthquake

Source:https://upload.wikimedia.org/wikipedia/commons/7/7c/Side_Effect_After_Earthquake_%28Nepal%29_Baisakh_2072_29.jpg

Frequency of earthquake occurrences

The earthquake is a natural hazard. If a tremor of high magnitude takes place, it can cause heavy damage to the life and property of people. However, not all the parts of the globe necessarily experience major shocks. The quakes of high magnitude, i.e. 8+ are quite rare; they occur once in 1-2 years whereas those of 'tiny' types occur almost every minute.

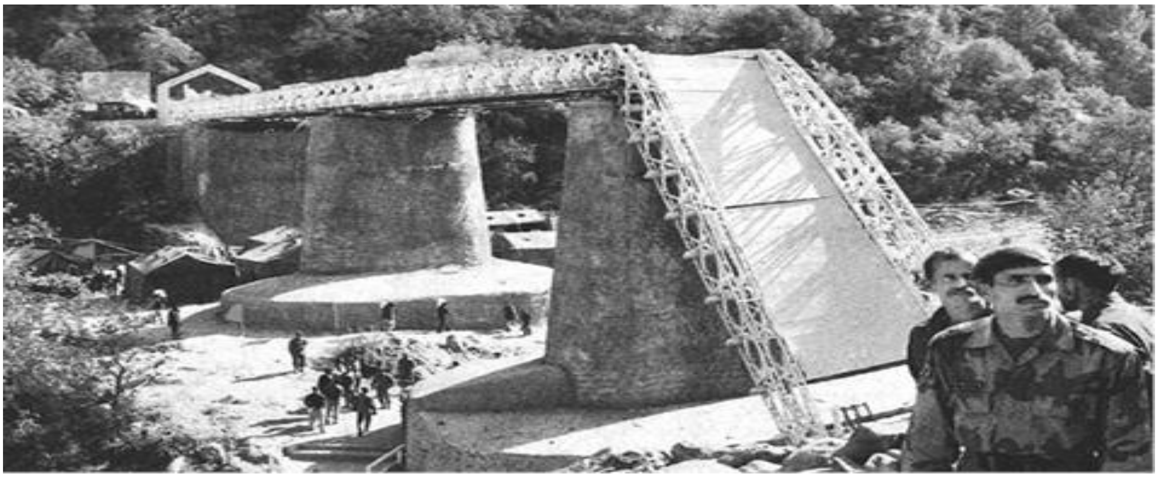

Fig. No. 08 Aview of the Damaged Aman Setu at the LOC In Uri ,due to an earthquake

Fig. No. 09 Earthquake in Onagawa, Miyagi, Japan.

Source:

https://upload.wikimedia.org/wikipedia/commons/e/e3/Rescue_team_from_India.JPG

As mentioned earlier the velocity of waves in particular the P-waves and S-waves changes as they travel through materials with different densities. The denser the material, the higher is the velocity. Their direction also changes as they reflect or refract when coming across materials with different densities. These properties of the waves have helped in understanding the material composition and thickness of the layers in the earth's interior.

Structure of the earth

The interior structure of the Earth is layered like an onion, in spherical shells of varying thickness. These layers can be defined based on their chemical and rheological properties. The earth has a solid outer crust, an intervening highly viscous layer within the solid mantle called the asthenosphere, an outer core that is much less viscous than the asthenosphere, and a solid inner core.

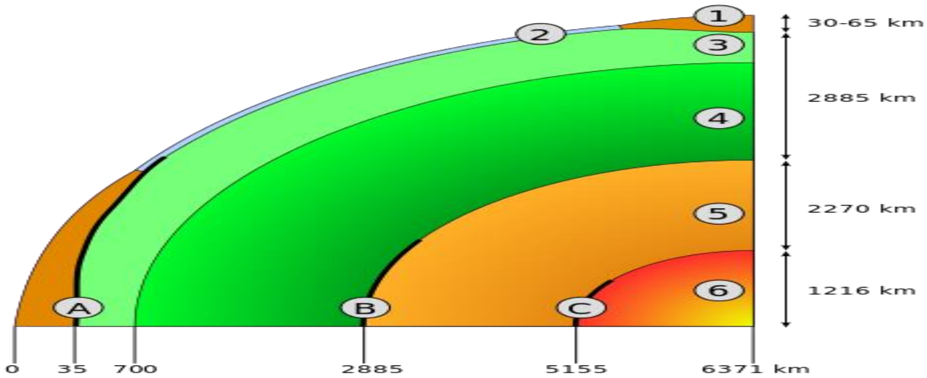

Fig. No. 10 Schematic view of the interior of Earth. 1. continental crust – 2. oceanic crust – 3. upper mantle – 4. lower mantle – 5. outer core – 6. inner core – A: Mohorovičić discontinuity – B: Gutenberg Discontinuity – C: Lehmann–Bullen discontinuity.

Source: https://en.wikipedia.org/wiki/Structure_of_the_Earth#/media/File:Slice_earth.svg

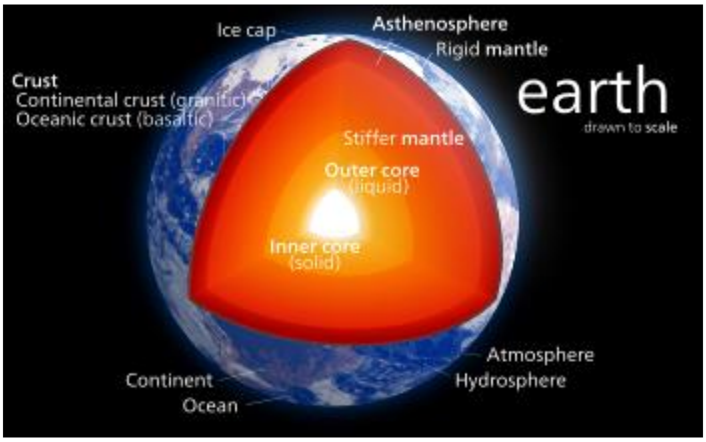

Fig. No.11 Structure of the earth

Source:https://upload.wikimedia.org/wikipedia/commons/thumb/0/07/Earth_poster.svg/1280px-Earth_poster.svg.png

The Crust

It is the outermost solid part of the earth. It is brittle in nature. The thickness of the crust varies under the oceanic and continental areas. Oceanic crust is thinner as compared to the continental crust. The mean thickness of oceanic crust is 5 km whereas that of the continental is around 30 km. The continental crust is thicker in the areas of major mountain systems. It is as much as 70 km thick in the Himalayan region.

Made up of igneous rocks the continental crust is underlaid by granites and heavier type of rock found in the oceanic crust is basalt. The mean density of material in crust is 2.7 g/cm^3.

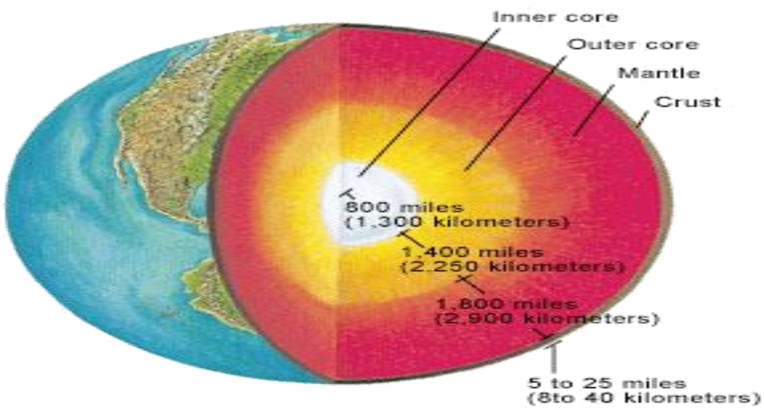

Fig. No.12 Earth's layers

Source : https://upload.wikimedia.org/wikipedia/commons/1/1b/Earth_layers_NASA.png

The Mantle

The portion of the interior beyond the crust is called the mantle. The mantle extends from Moho's discontinuity to a depth of 2,900 km. The intervening layer on the upper portion of the mantle is called asthenosphere. The word astheno means weak. It is considered to be extending upto 400 km. It is the main source of magma that finds its way to the surface during volcanic eruptions. It has a density higher than the crust's (3.4 g/cm^3). The crust and the uppermost part of the mantle are called lithosphere. Its thickness ranges from 10-200 km. The lower mantle extends beyond the asthenosphere. It is in solid state.

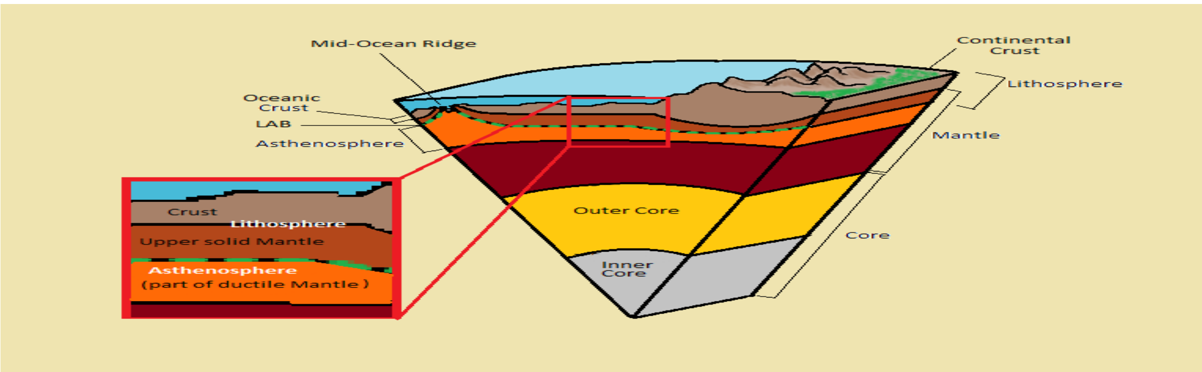

Fig. No 13: Layers in earth's interior

Source:https://upload.wikimedia.org/wikipedia/commons/2/22/Earth%27s_Inner_Layers_denoting_the_LAB.png

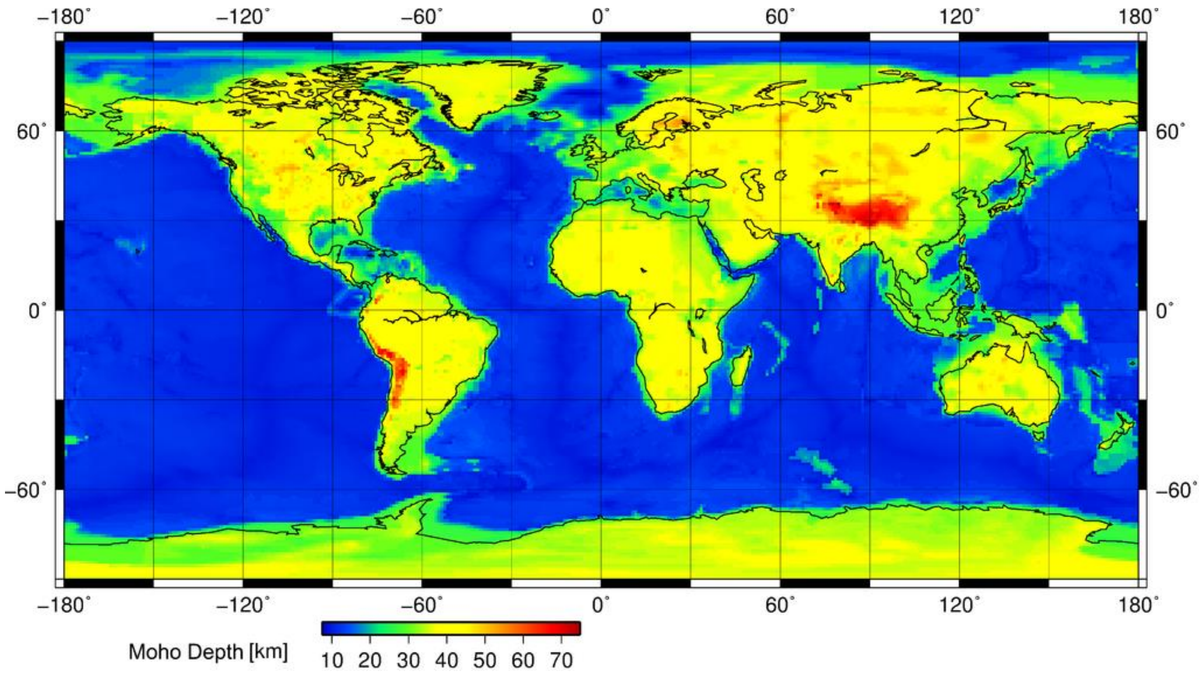

Fig. No 14; World map showing the position of the Moho.

The Core

Study of seismogram

As indicated earlier, the earthquake wave velocities helped in understanding the existence of the core of the earth. The core mantle boundary is located at the depth of 2,900 km. The outer core is in liquid state while the inner core is in solid state. The density of material at the mantle core boundary is around 5 g/cm^3 and at the centre of the earth at 6,300 km, the density value is around 13g/cm^3. The core is made up of very heavy material mostly constituted by nickel and iron. It is sometimes referred to as the NiFe layer.

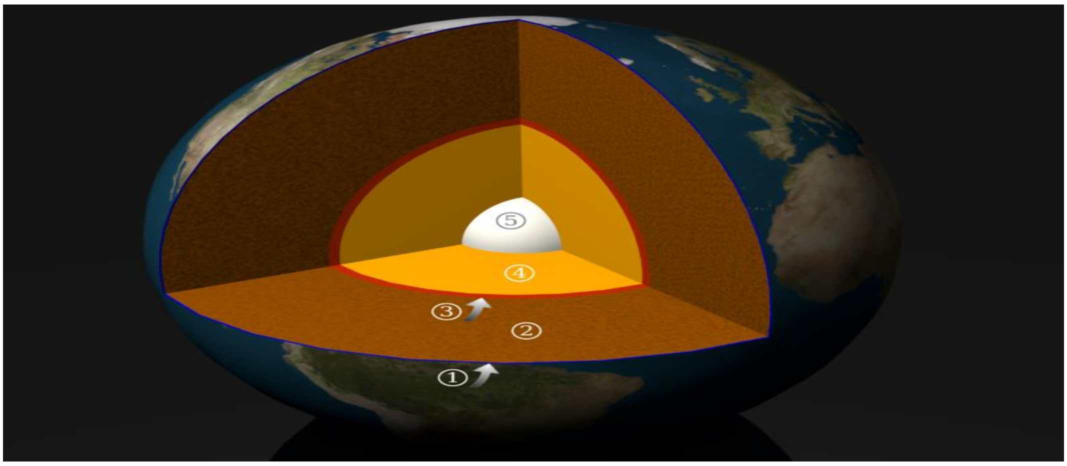

Fig. No 15 The earth's core

Source : https://en.wikipedia.org/wiki/File:Earth-layers-01.png