Earth's Interior With Special Reference to Seismology

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STRUCTURE OF THE EARTH'S INTERIOR

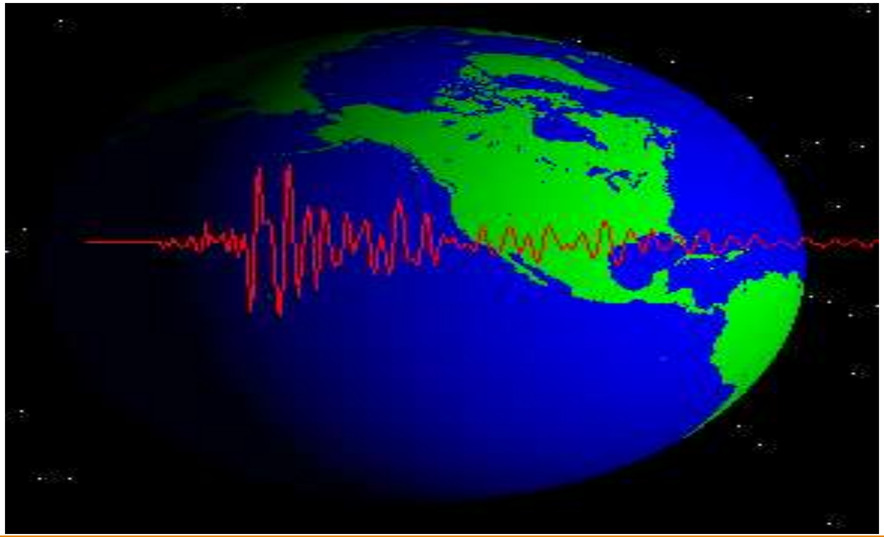
The study of the Constitution of the interior of the earth is outside the domain of geography.

Why the elementary knowledge about the interior of the earth is necessary for the geographers??

- ***The nature and configuration of the reliefs of the earth's surface largely depend on the nature, mechanism and magnitude of the endogenetic forces which originate from within the earth.***

- It is decidedly true that it is very difficult task to have accurate knowledge of the constitution of the earth’s interior because it is beyond the range of direct observation by man.

- Recently seismology has helped to have some authenticated knowledge about the mystery of the earth’s interior.



Seismology is the study of earthquakes and seismic waves that move through and around the earth.

A **seismologist** is a scientist who studies earthquakes and seismic waves.

What Are Seismic Waves? Seismic waves are the waves of energy caused by the sudden breaking of rock within the earth or an explosion.

Sources of Knowledge about the interior of the earth

- Artificial sources

- Evidences from the theories of the origin of the earth

- Natural sources: Vulcanicity, Seismology

Artificial Sources

Numerous inferences can be drawn about the constitution of the interior of the earth on the basis of :

- *density of rocks*
- *pressure of superincumbent load (weight of overlying rocks)*
- *increasing trend of temperature with increasing depth inside the earth*

DENSITY

- It is commonly believed that the outer thinner part of the earth is composed of sedimentary rocks, the thickness of which ranges between half a mile to one mile (0.8 km. to 1.6 km.)
- Just below this sedimentary layer there is the second layer of crystalline rocks, the density of which ranges between 3.0 g/cm^3 and 3.5 g/cm^3
- The average density of the whole earth is about 5.5

- Thus, it appears that the density of the core of the earth will be, without doubt, more than 5.5.

- Generally the average density of the core of the earth is around 11.

- Since 1950, several attempts are being made to calculate the density of the earth on the basis of satellites.

- The satellite studies have revealed the following results about the density of various parts of the earth:

- average density of the earth-5.517
- average density of the earth's surface-2.6 to 3.3
- average density of the core-11

- ***Thus it is proved that, the density of the core of the earth is highest of all parts of the earth.***

PRESSURE

- *What is the reason for very high intensity of the core?*
- It is common principle that pressure increases the density of rocks. So it is assumed that the high density of the core of the earth is due to very high pressure prevailing there because of heavy weight of overlying rocks.
- This inference is proved wrong on the ground that there is a critical limit in each rock beyond which the density of that rock cannot be increased inspite of increasing pressure therein.

- It may be thus forwarded that :

Very high density of the core of the earth is not because of high pressure of overlying rocks. So the core must be composed of intrinsically heavy metallic minerals of high density.

TEMPERATURE

- It is evident on the basis of information available from the findings of deep mining that temperature increases from the surface of the earth downward at the rate of 1deg. Celsius for 32 metres.
- In tectonically active areas the temperature at the lower part of the continental (Sial) and oceanic (Sima) crust which come in contact with the asthenosphere at the depth of 43km-48 km is between 1000-1200 deg. Celsius which is nearer to the initial melting point of the rocks.

- The rocks and minerals cannot remain in a solid state at such a high temperature. It is therefore inferred that the source of lava eruption of the volcanoes is the partly molten Asthenosphere which is at a depth of about 43 km-48 km.
- If we believe in the rate of general increase of temperature with increasing depth, the temperature should have been more than 25000 deg. Celsius at the depth of 2900 km which is far from reality (about 3700 deg. Celsius).

- So it can be clearly assumed that *the rate of increase of temperature inside the earth undergoes a sharp decrease at greater depths from the surface.*

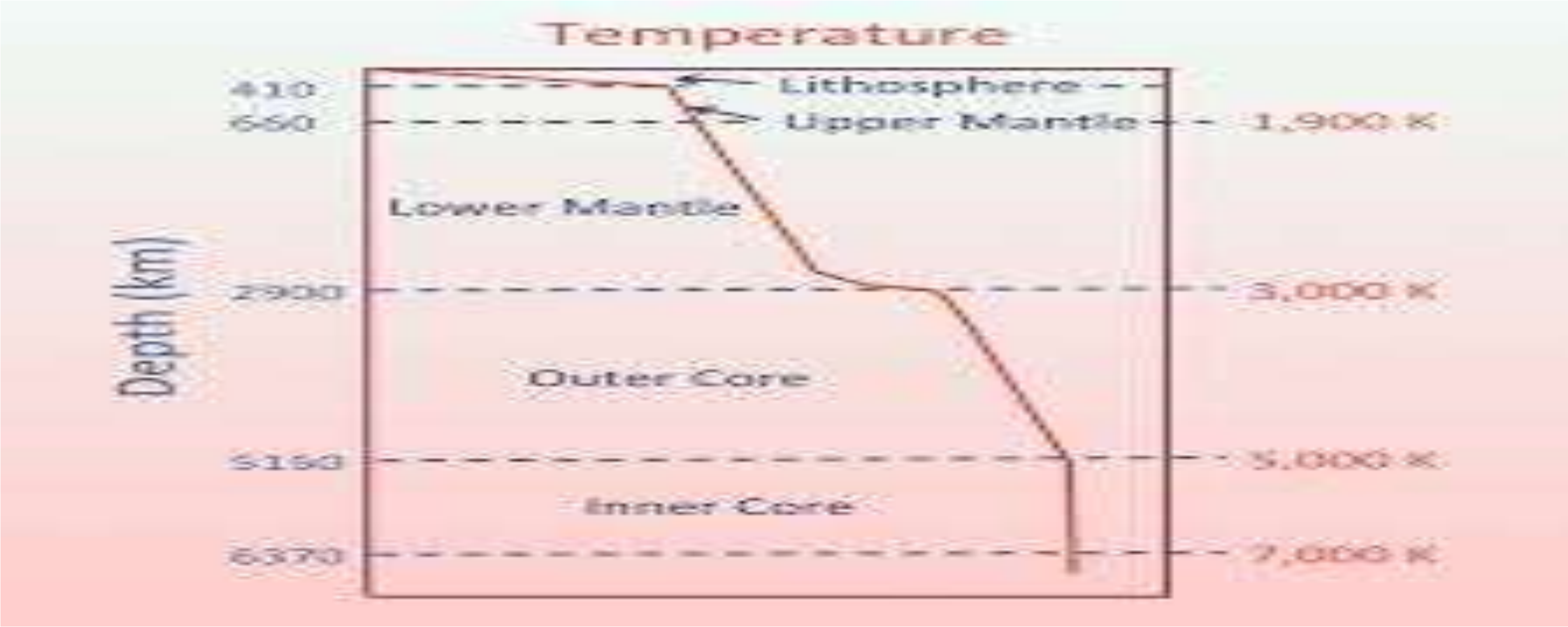
- In the upper layers of the earth an important source of the heat is radio-active minerals like Uranium and Thorium. These minerals are more abundant up to the depth of about 100 km, below which they are found in much lesser quantities. This fact explains the situation of high temperature in the crustal areas due to disintegration and decay of radio-active minerals generating more heat.

- The thermal conditions of the interior of the earth may be summarized as under:

- At the depth of about 48 km (from the earth's surface) the temperature is about 1000-1200 deg. Celsius.
- The temperature at the depths of 400 km. and 700 km. is about 1500 deg. Celsius and 2000 deg. Celsius respectively.

- The temperature at the junction of the mantle and the outer molten core standing at the depth of 2900 km. is about 3700 deg. Celsius.

- The temperature at the junction of the outer molten core and the inner solid core standing at the depth of 5100 km. is about 4300 deg. Celsius.



Evidences from the theories of the origin of the earth

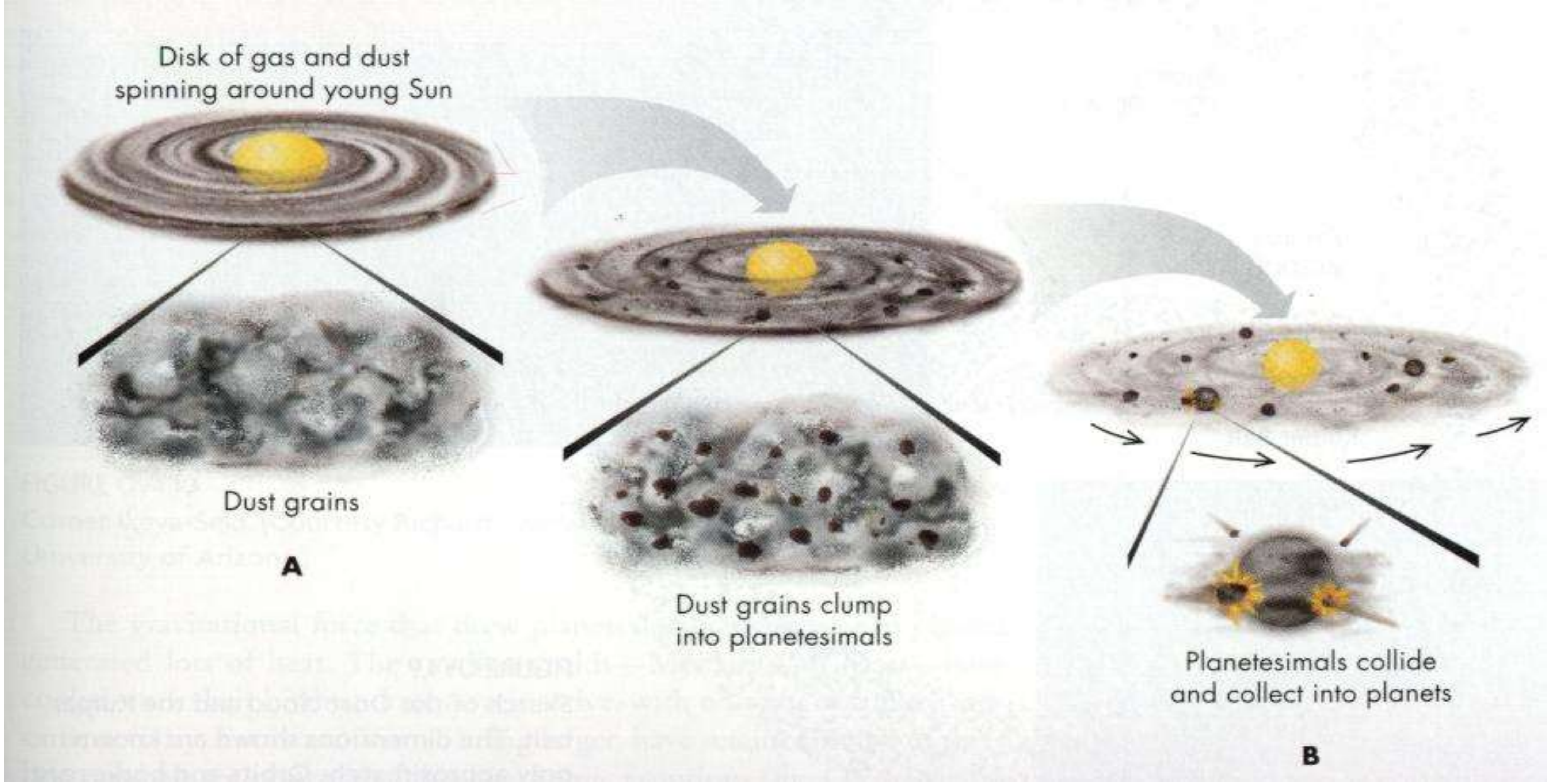
- Various exponents of different hypotheses and theories of the origin of the earth have assumed the original form of the earth in various states.

Planetesimal Hypothesis

According to this theory the earth was originated due to accretion and aggregation of solid dust particles known as ‘planetesimals’..

Based on this theory it can be assumed that the core of the earth should be in solid state..

Planetesimal Hypothesis



Tidal Hypothesis

According to this hypothesis the earth has been formed from the tidal materials ejected from the primitive sun….

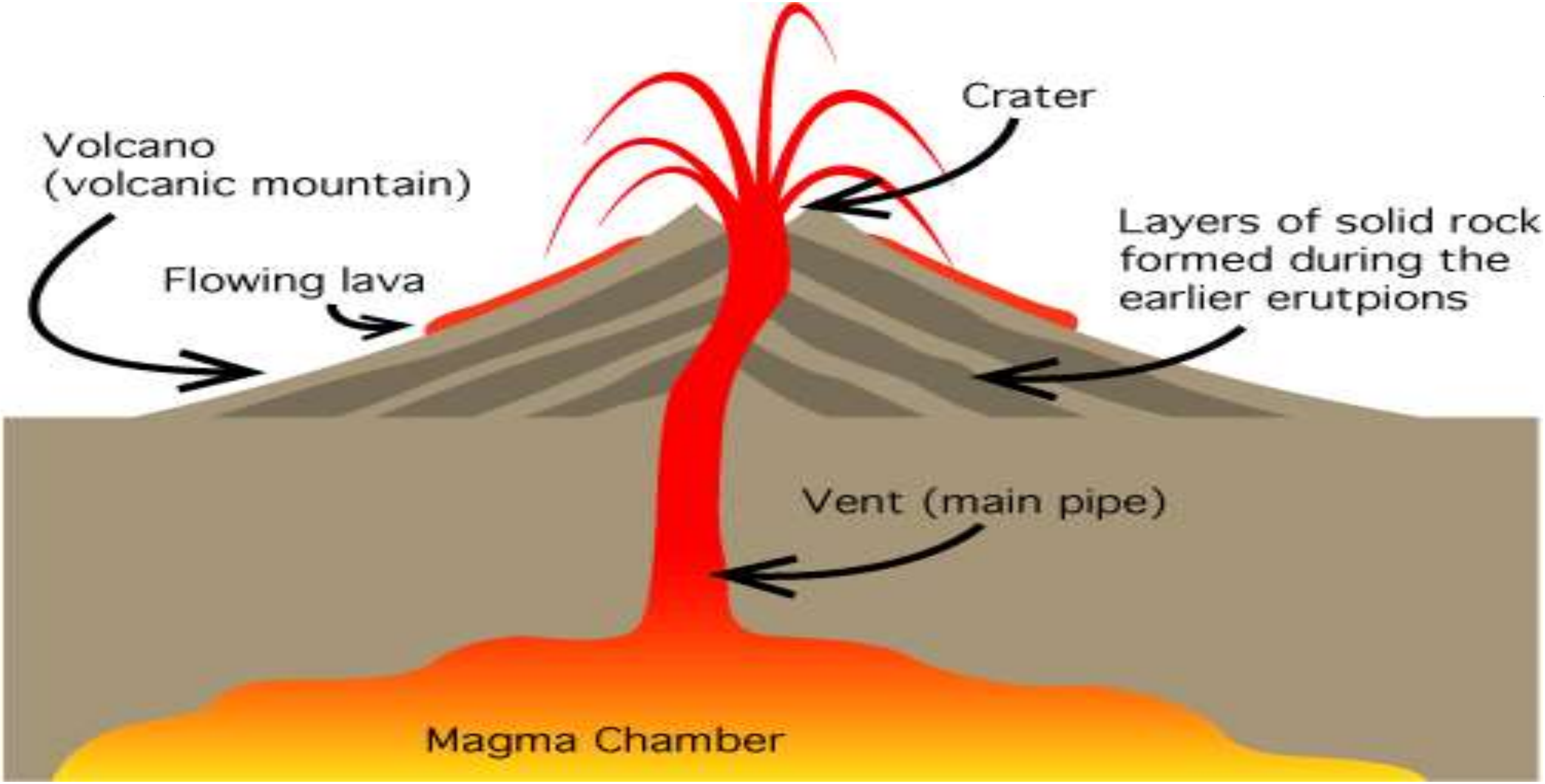
Based on this theory it can be assumed that the core of the earth should be in liquid state…

Tidal Hypothesis

Natural Sources
VULCANICITY

- Some scientists believe on the basis of upwelling and spread of hot and liquid lava on the earth's surface which is in liquid state during volcanic eruption that there is at least such a layer below the earth's surface which is in liquid state. Such molten layer has been termed as 'magma chamber' which supplies magma during volcanic eruptions.

Volcanic eruption and Magma Chamber



- Inference: So part of the earth should be in liquid state….

- Pressure increases with increasing depth inside the earth. Increasing pressure increases the melting points of the rocks. Thus the inner part of the earth may not be in molten state inspite of very high temperature as the pressure of the overlying rocks increases the melting point of the rocks.
- As a result, the above inference may be refused.

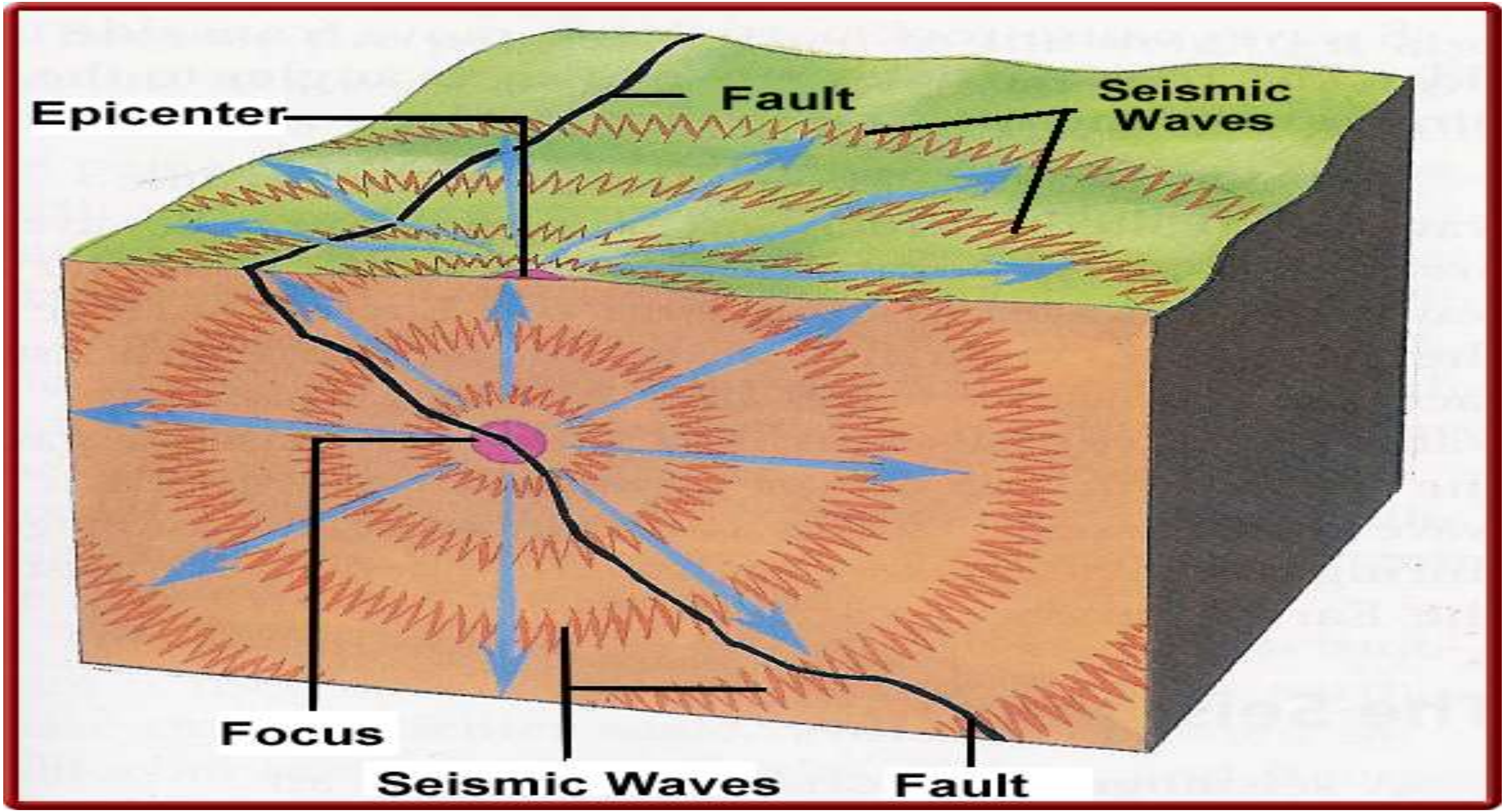
- Inference: The core of the earth should be in solid state…

- Now question arises, *where from hot and liquid magma come during volcanic eruption?*
- The pressure of overlying rocks is reduced due to due to fracturing and faulting in the crustal surface, the melting point of underlying rocks is reduced and the rocks are melted because of prevailing high temperature.

No authenticated knowledge about the composition of the earth's interior is obtained from the evidences of volcanic activities.

Evidences of Seismology

- The behavior of seismic waves in the different layers of the earth provides the most authentic evidence about the composition and structure of the earth.
- The place of the occurrence of an earthquake inside the earth is called '***focus***'.
- The place on the earth's surface which experiences the seismic event first is called ***'epicentre'***.



Epicenter
Fault
Seismic Waves
Focus
Seismic Waves
Fault

- The different types of waves generated during the occurrence of an earthquake are called ***'seismic waves'*** which are generally divided into three broad categories:

  1. **Primary waves**
  2. **Secondary waves**
  3. **Surface waves**

PRIMARY WAVES

- also called longitudinal or compressional waves or simply ‘P’ waves.
- analogous to sound waves wherein particles move both to and fro in the line of the ray.
- short wave length, high frequency
- travels with fastest speed through solid materials but their speed is slowed down while passing through liquid materials.

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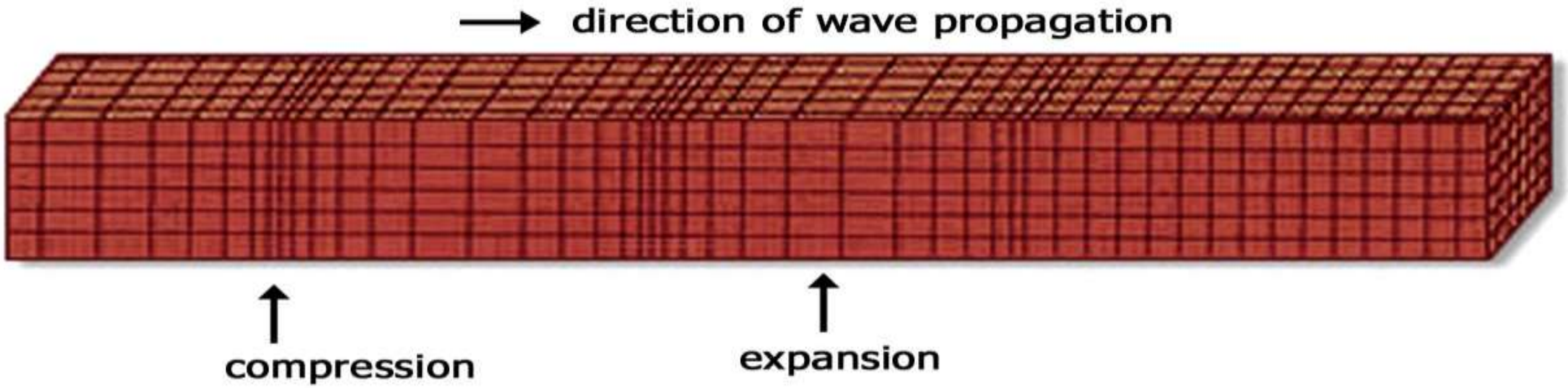
Primary waves

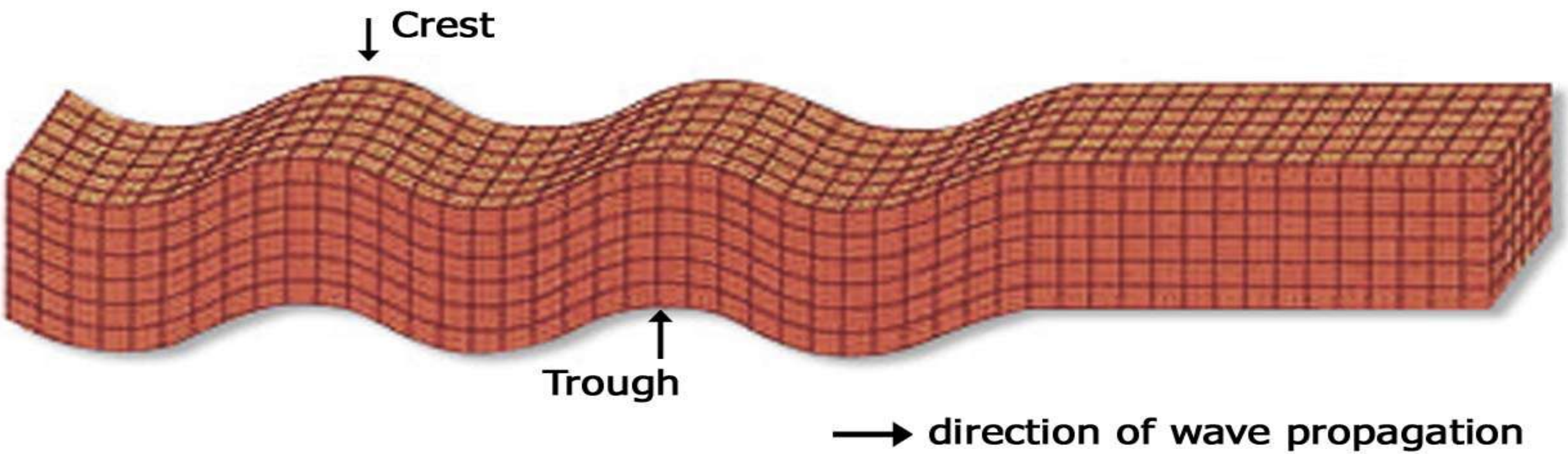


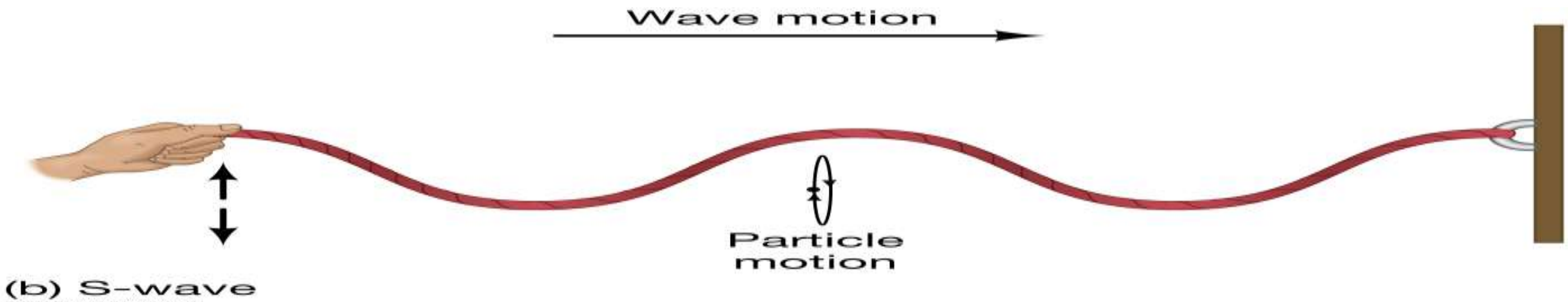
SECONDARY WAVES

- also called as transverse or simply ‘s waves’.

- analogous to water ripples or light waves wherein the particles move at right angles to the rays.
- short wave length, high frequency.
- travel through solid materials, cannot pass through liquid materials.

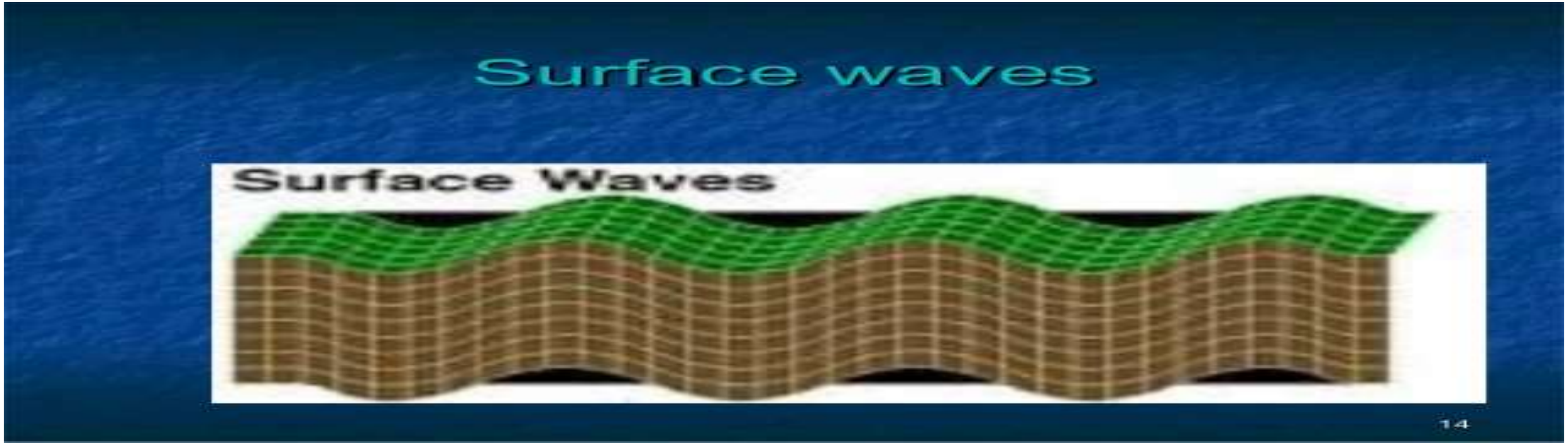
Secondary waves

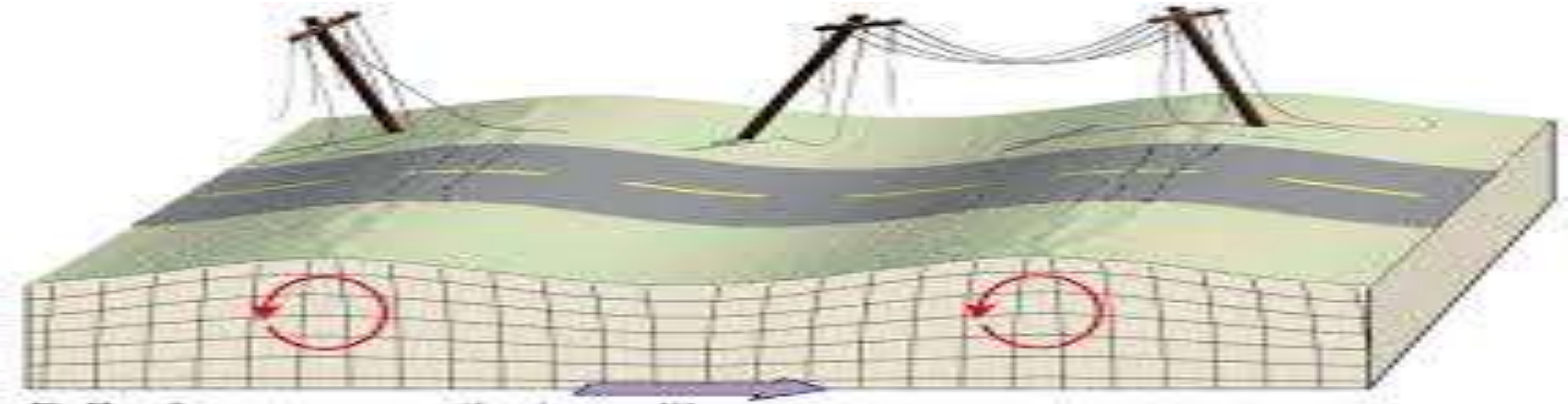




SURFACE WAVES

- also called as long period waves or simply ‘L waves’.
- generally affect only the surface of the earth.
- long wave length and low frequency
- develop in the immediate neighbourhood of the epicenter.
- cover the longest distance of all the seismic waves.
- speed is lower than P and S waves, most destructive





F. Surface waves that are like ocean waves

The nature and properties of the composition of the interior of the earth may be successfully obtained on the basis of the study of various aspects of seismic waves.

The path of Seismic variations are more or less governed by laws similar to those of optics. So seismic vibrations move in a straight line through a homogeneous body.

Seismic waves are reflected and refracted while passing through a body having heterogeneous composition and varying density.

If the earth would have been composed of homogeneous solid materials the seismic waves should have reached the core of the earth in a straight path but this is not the case in reality.

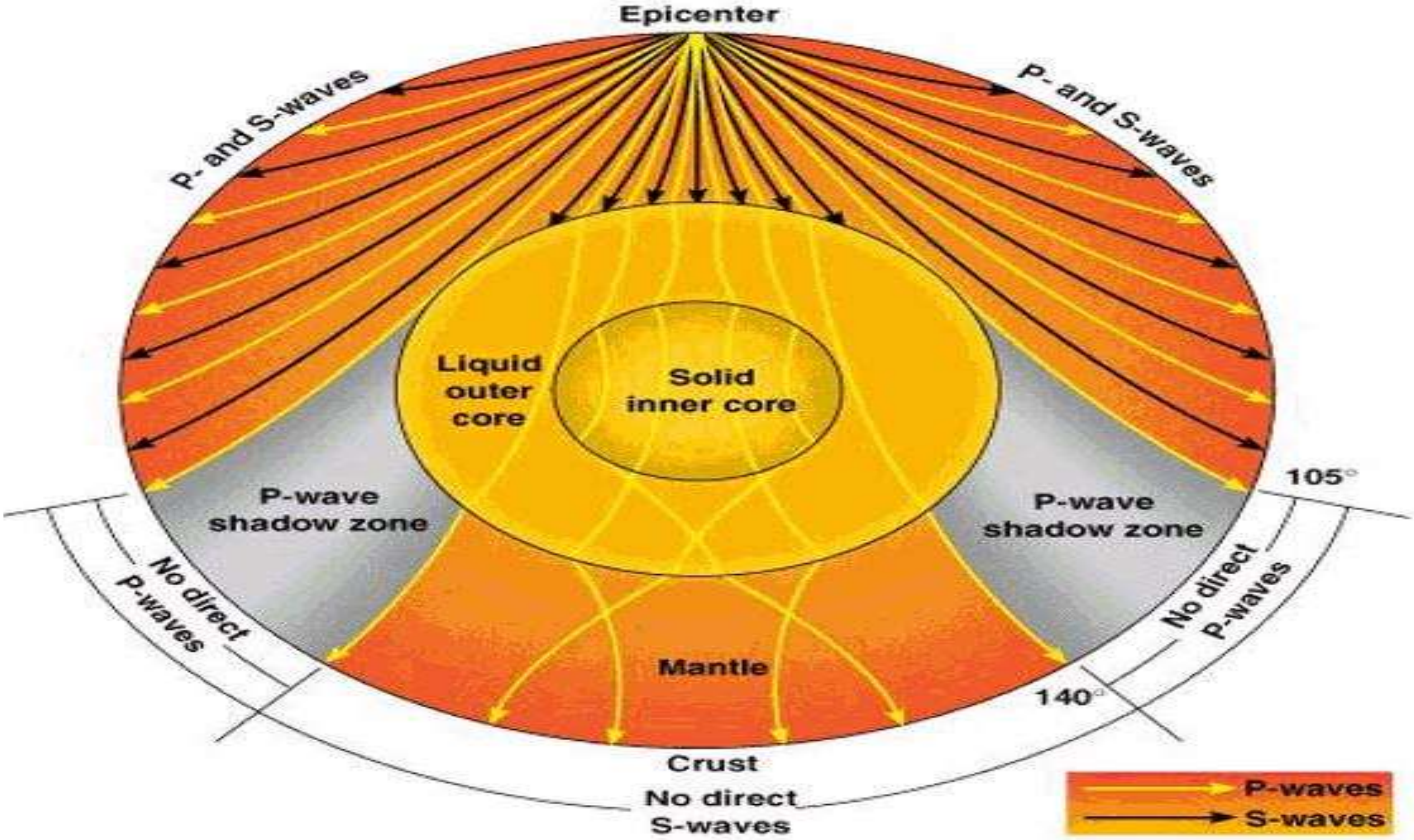
In fact the recorded seismic waves denote the fact that these waves seldom follow straight paths rather they adopt curved and refracted paths.

Thus it becomes obvious that the earth is not composed of homogeneous materials rather there are variations of density inside the earth. The seismic waves are refracted at the places of density changes. Thus the seismic waves become concave towards the earth's surface.

- Indepth study of seismic waves reveals that S Waves disappear at the angular distance of 103 deg. From the epicenter.

- Thus there is a huge shadow zone extending almost half way around the earth, opposite the earthquake's epicenter.
- S waves cannot be transmitted through the liquid.
- It appears that the outer core is in liquid state at the depth of about 2900 km from the surface.

- P waves disappear between the angular distance of 103 deg. and 143 deg. from the epicenter.
- The refraction of P waves at the boundary between the core and the mantle thus causes a P wave shadow zone (between 103 deg. and 143 deg. From the epicenter)
- P waves are refracted through the core and emerge between 143 deg. and 180 deg. from the epicenter.
- This suggests the presence of a solid inner core and a liquid outer core.


Epicenter
P- and S-waves
P- and S-waves
Liquid outer core
Solid inner core
P-wave shadow zone
P-wave shadow zone
105°
No direct P-waves
No direct P-waves
Mantle
140°
Crust
No direct S-waves
P-waves
S-waves

- On the basis of velocity, the body seismic waves have been further divided into three sets of waves:

- First set of P-S waves of maximum velocity
- Second set of Pg-Sg waves of mimimum velocity
- Third set of P*-S* waves of medium velocity.

STRUCTURE OF EARTH'S INTERIOR

- *CRUST*:
  - The outermost layer or shell of the earth with a avg. depth of 35 km.
  - Divided into two sub zones:

    1. Lower crust or Oceanic crust (Sima)
    2. Upper crust or Continental crust (Sial)

- The difference of density between the upper (2.8) and lower crust (3.0) is because of the pressure of superincumbent load.

- This division is on the basis of the change in velocity of seismic waves.
- The average velocity of P waves in the upper crust is 6.1 km/sec and in the lower crust is 6.9 km/sec.
- The Conrad Discontinuity separates the Upper crust from the lower.

MANTLE:

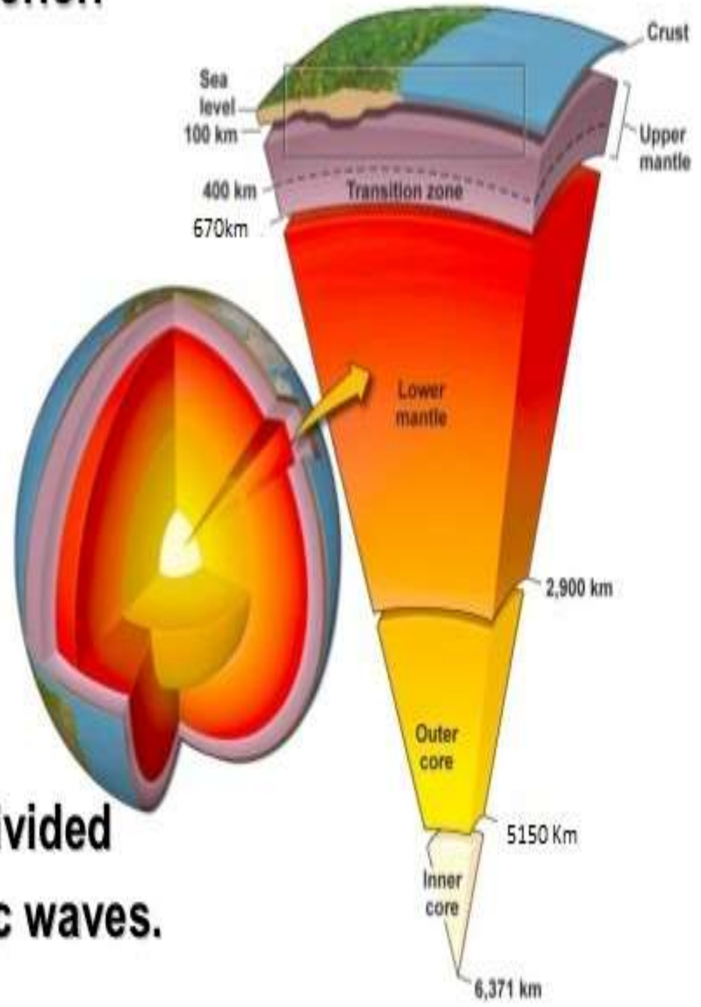
- Separated from the crust by Moho Discontinuity which is characterized by a sudden increase in the velocity of seismic waves (from 6.9 km/sec to 8.1 km/sec) upto 100 km.
- The velocity of seismic waves relatively slows down from a depth of 100 km-200 km (Zone of low velocity)
- The zone of low velocity is the asthenosphere: zone of partly molten material.

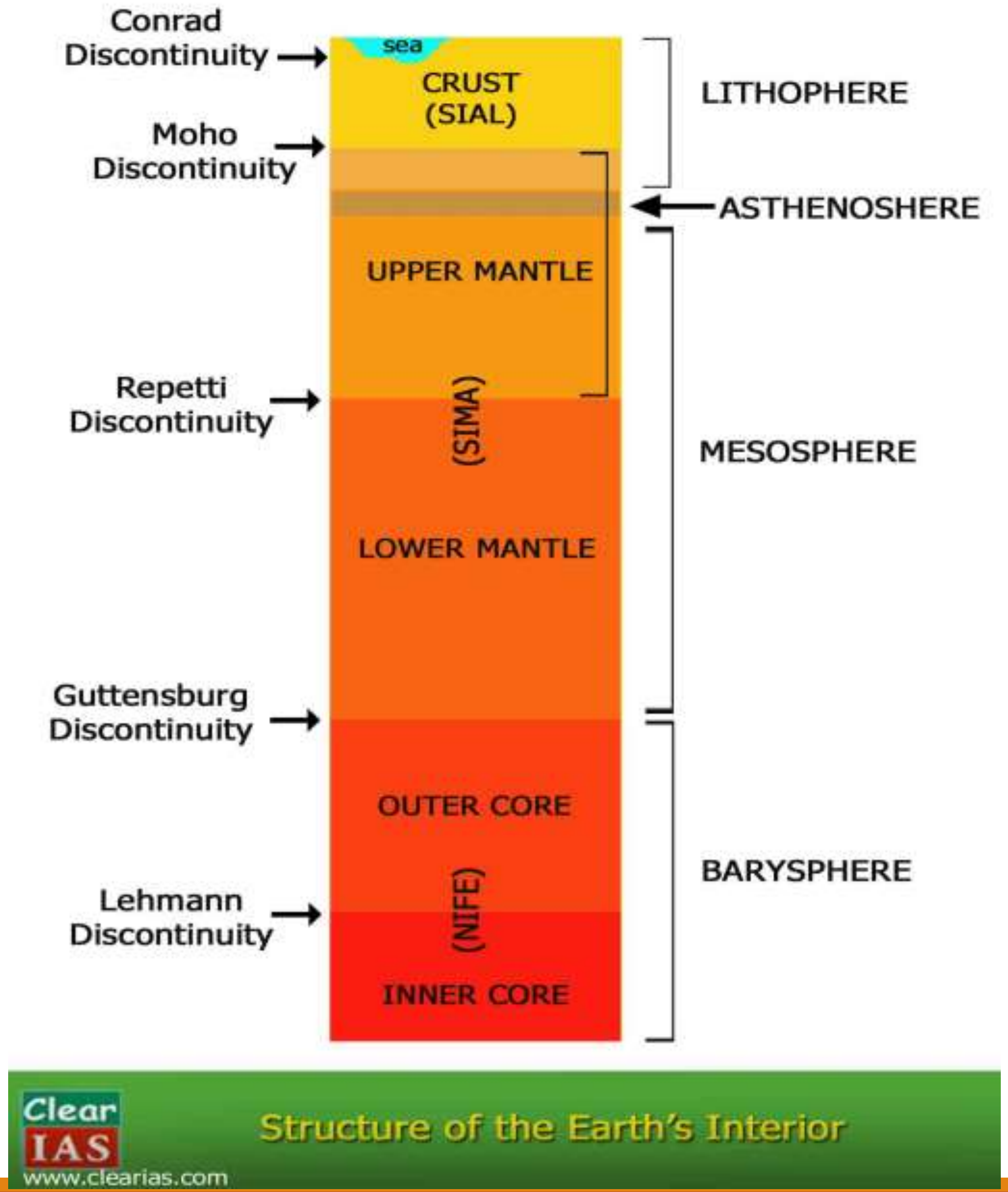
- Below 200 km beneath the surface the velocity of seismic waves increases until the depth of about 2900 km (the depth of mantle) where both velocities change abruptly.
- Mantle has been divided into two zones:

  1. Upper mantle: upto depth of about 700 km
  2. Lower mantle: upto the depth of about 2900 km
- The mantle is composed of dense and rigid rocks which contain minerals like iron and magnesium.
- Upper and lower mantle seperated by : Repetti Discontinuity
- Density ranges from 3.3to 5.7.

Summarizing Earth's Layers

- Earth has a layered interior.
  - Crust
    - Continental
    - Oceanic
  - Mantle
    - Upper
    - Transitional
    - Lower
  - Core
    - Outer—liquid
    - Inner—solid
- These layers are subdivided on the basis of seismic waves.





❑ *CORE*:

- The deepest and most inaccessible zone of the earth.
- extends from the lower part of the mantle to the centre of the earth (2900 km-6371 km).
- The mantle-core boundary is determined by the ‘Weichert-Gutenberg Discontinuity’ which is characterized by a sudden increase in the velocity of P waves (13.7 km/sec).
- Core is divided into two zones:

  1. Outer Core
  2. Inner Core

- At the outer core boundary (depth of 2900 km) S waves suddenly disappear and the velocity of P waves abruptly decreases from 13.7 km/sec to 8 km/sec indicating a liquid outer core.
- In the inner core P waves are deflected and travel at a speed of 11.23 km/sec indicating its solid state.
- The outer and inner core is separated by Lehmann Discontinuity at a depth of about 5150 km.
- Density of core ranges from 9.5 to 14.5.
- It is generally believed that the core is composed of iron and nickel (nife)

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