

# Earth's Interior, Earthquake, and Seismicity

Master Course on Geomorphology (Unit I) - NTA UGC NET 2022

**Master Course on  
Geomorphology**

**NTA UGC NET  
2022**

**Earth's Interior,  
Seismicity &  
Earthquake**

**By Abhishek Kumar Jha (Research Scholar UGC-SRF)**



# Abhishek Kumar Jha

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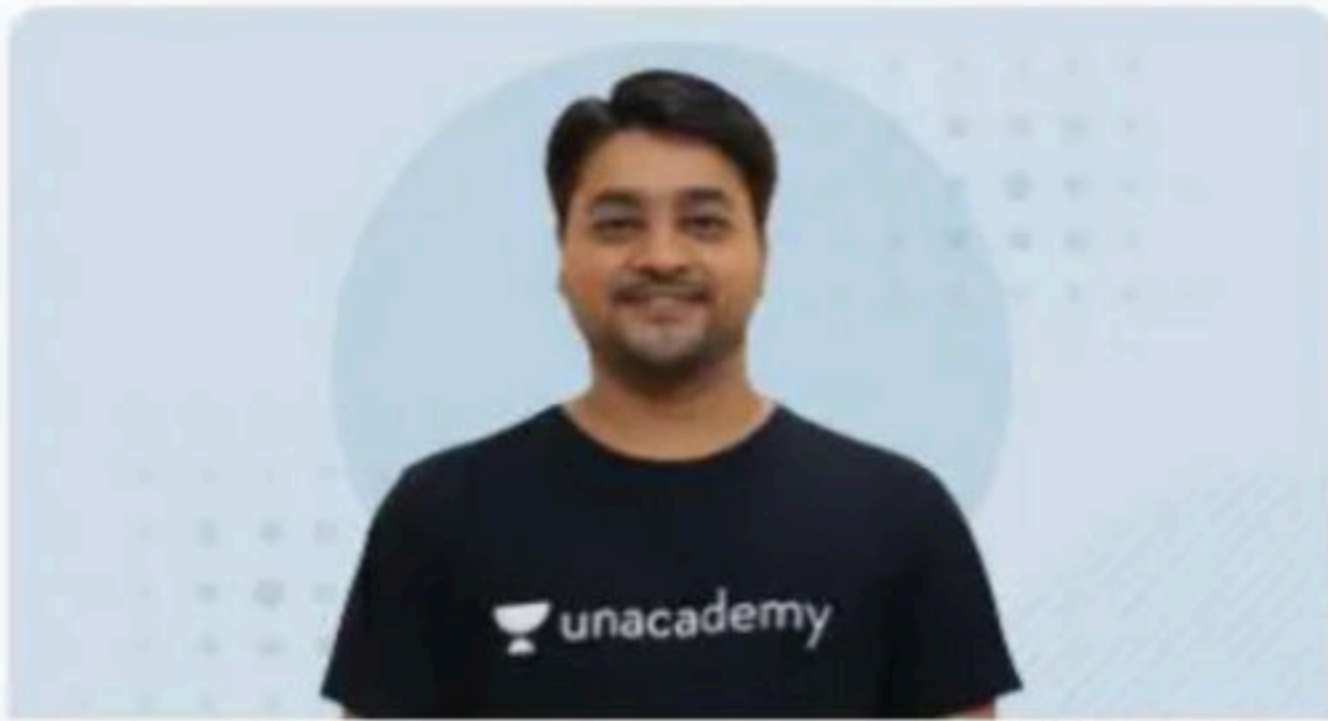
### Abhishek Kumar Jha

- Home Town Sultanpur, Uttar Pradesh, Brought up in Varanasi, Uttar Pradesh
- Lives in Delhi, India
- Former Professional Cricket Player
- Graduated in Geography from Banaras Hindu University (BHU)
- Masters in Geography from Banaras Hindu University (BHU)
- Masters in Rural Development from IGNOU
- Qualified Various Entrance based examinations of BHU, JNU, DU.
- Diploma & Certificate Course in Yoga from Banaras Hindu University (BHU)
- Qualified JRF & cleared UGC NET JRF exam 6 times
- Cleared UPSC Pre – 2016 and Qualified for UPSC mains
- Qualified Haryana Assistant Professor Exam (College Cadre - 2017) & given interview (HPSC)
- Currently pursuing PhD (UGC-SRF) from V.B.S. Purvanchal University, Uttar Pradesh
- Have 8 years of teaching experience for NTA UGC NET and Mentored 3300+ students for UGC NET so far.
- **NTA UGC NET June 2020 Result: 75+ JRF & 150+ NET**
- **NTA UGC NET Dec 2020 & June 2021 Result: 170+ JRF & 400+ NET**
- **PGT/Asst. Prof. Results**



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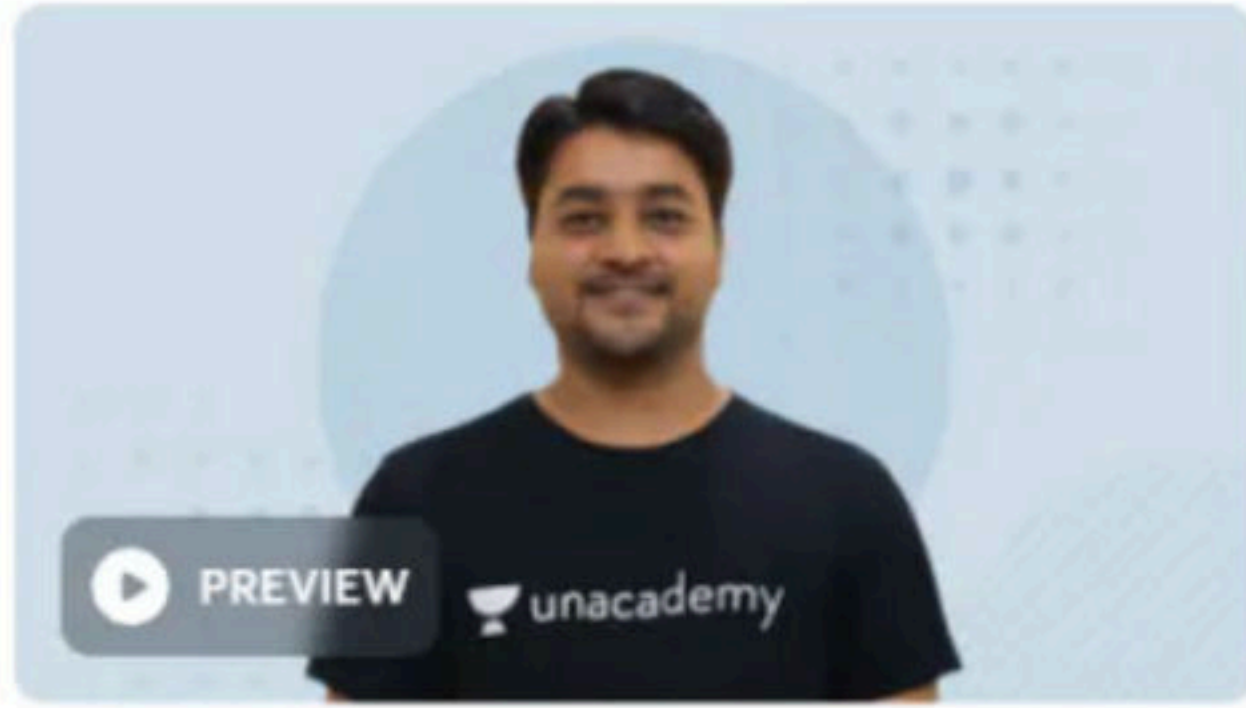


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# Sources of Information about the Interior of the Earth

## A. Direct Sources

1. **Rocks** from mining area
2. **Volcanic eruptions**

## B. Indirect Sources

1. By analyzing the **rate of change of temperature and pressure** from the surface towards the interior.
2. **Meteors**, as they belong to the same type of materials earth is made of.
3. **Gravitation**, which is greater near poles and less at the equator.
4. **Gravity anomaly**, which is the change in gravity value according to the mass of material, gives us information about the materials in the earth's interior.
5. **Magnetic sources**, Deep earth mining and drilling.
6. **Seismic Waves**: the shadow zones of body waves (Primary and secondary waves) give us information about the state of materials in the interior.

## Interior of The Earth

- The planet Earth is made up of three main shells: the very thin, **crust, the mantle, and the core**. The mantle and core are each divided into two parts. Although the core and mantle are about equal in thickness, the core actually forms only **15 percent** of the Earth's volume, whereas the mantle occupies **84 percent**. **The crust makes up the remaining 1 percent.**

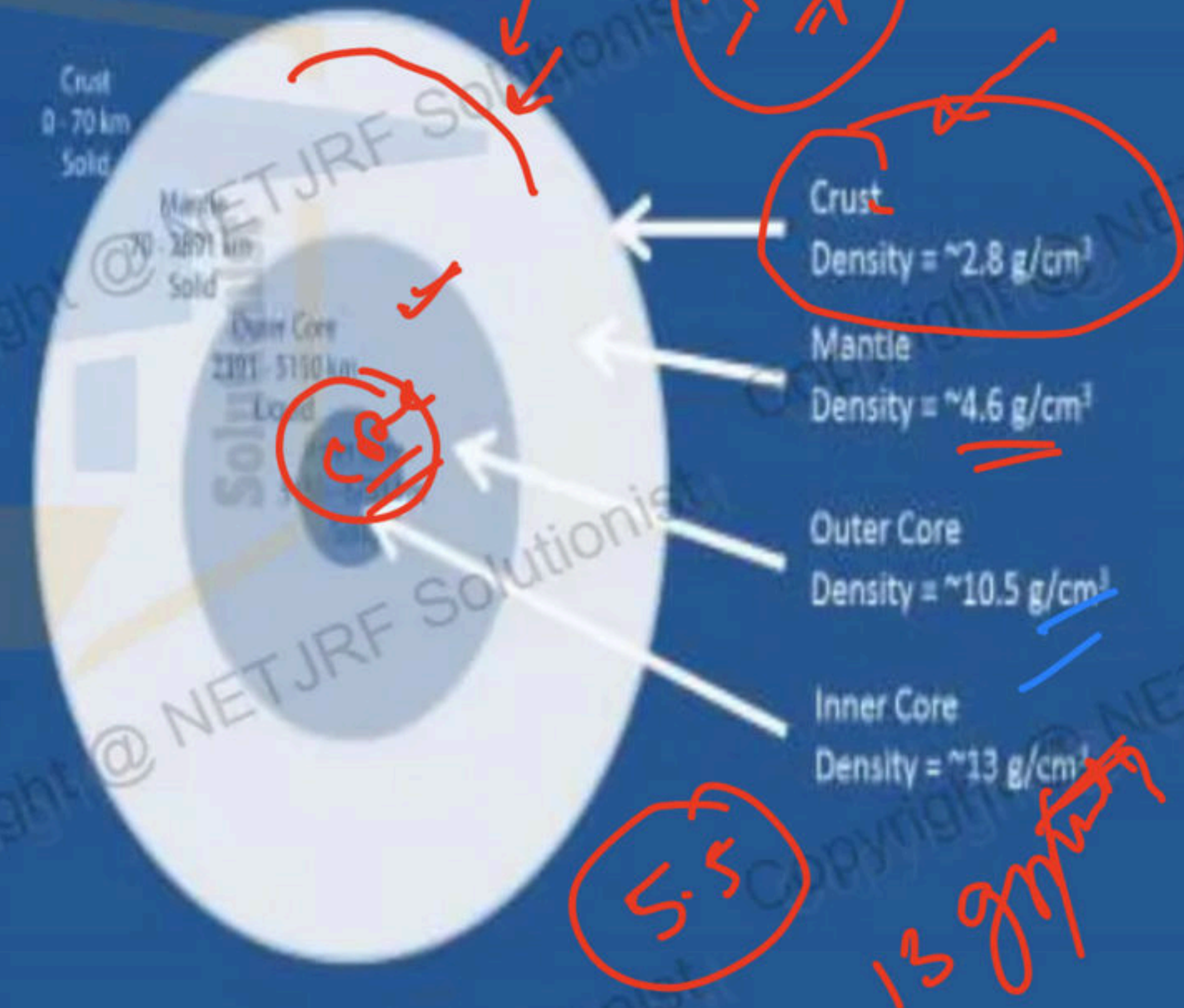
## About Earth's interior

- Understanding of the earth's interior is essential to understand the **nature of changes that take place over and below the earth's surface**.
  - To understand geophysical phenomenon like volcanism, earthquakes etc..
  - To understand the internal structure of various solar system objects
  - To understand the evolution and present composition of atmosphere
  - Future deep-sea mineral exploration etc.
- On an average, the temperature increases at a rate of 1° C for every 32 metres as one goes deep inside the Earth's interior.** The source of volcanic eruptions is considered to be at a depth of 48 kilometres inside the Earth's interior. But, it is only true for first 8 kilometres of depth inside the Earth beyond which it is very difficult to gauge the temperature values. Temperature values keep on progressively declining at far greater depths beyond 100 kilometres. Reason for this is the gradual decline in the availability of two heat sensitive radioactive minerals of uranium and thorium respectively.

## Density of The Earth's Interior

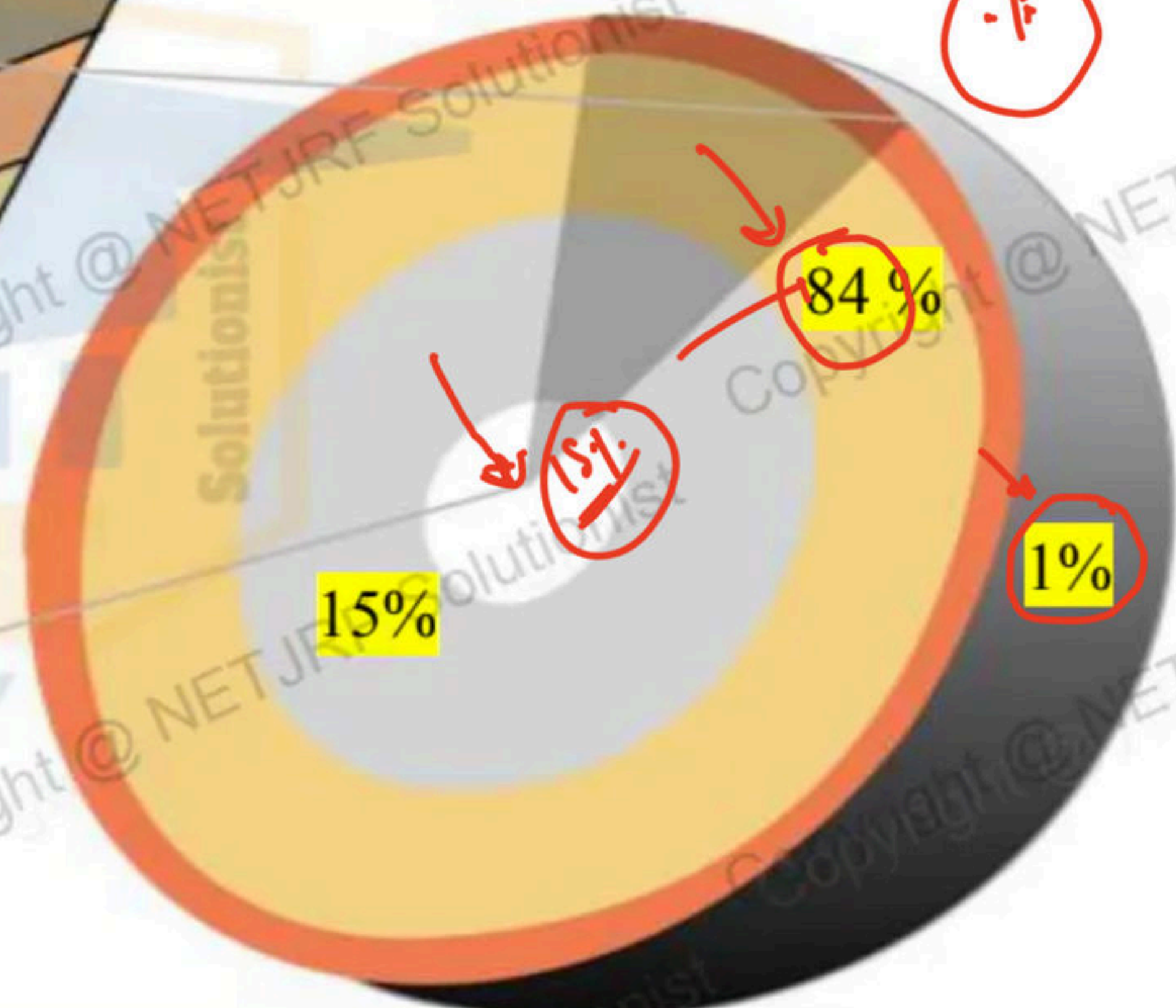
- On an average, the density of the Earth's interior is 5.5. However, it is 2.7 in the continental shells i.e. upper surface layers which consist of granitic rocks and sial i.e. **silica and aluminium**.
- It is also believed by the Earth scientists, particularly geologists that the density of material increases directly in proportion to the depth. In other words, **the density of materials increases as one goes down into the Earth's interior parts.**
- Density of materials found in the core layers of the Earth are around dozen times denser compared to the water. **Iron and nickel together known as 'nife'** forms the core layer of the Earth's interior.

Density increases as you travel from the crust to the inner core.



Exosphere  
Thermosphere  
Mesosphere  
Stratosphere  
Troposphere

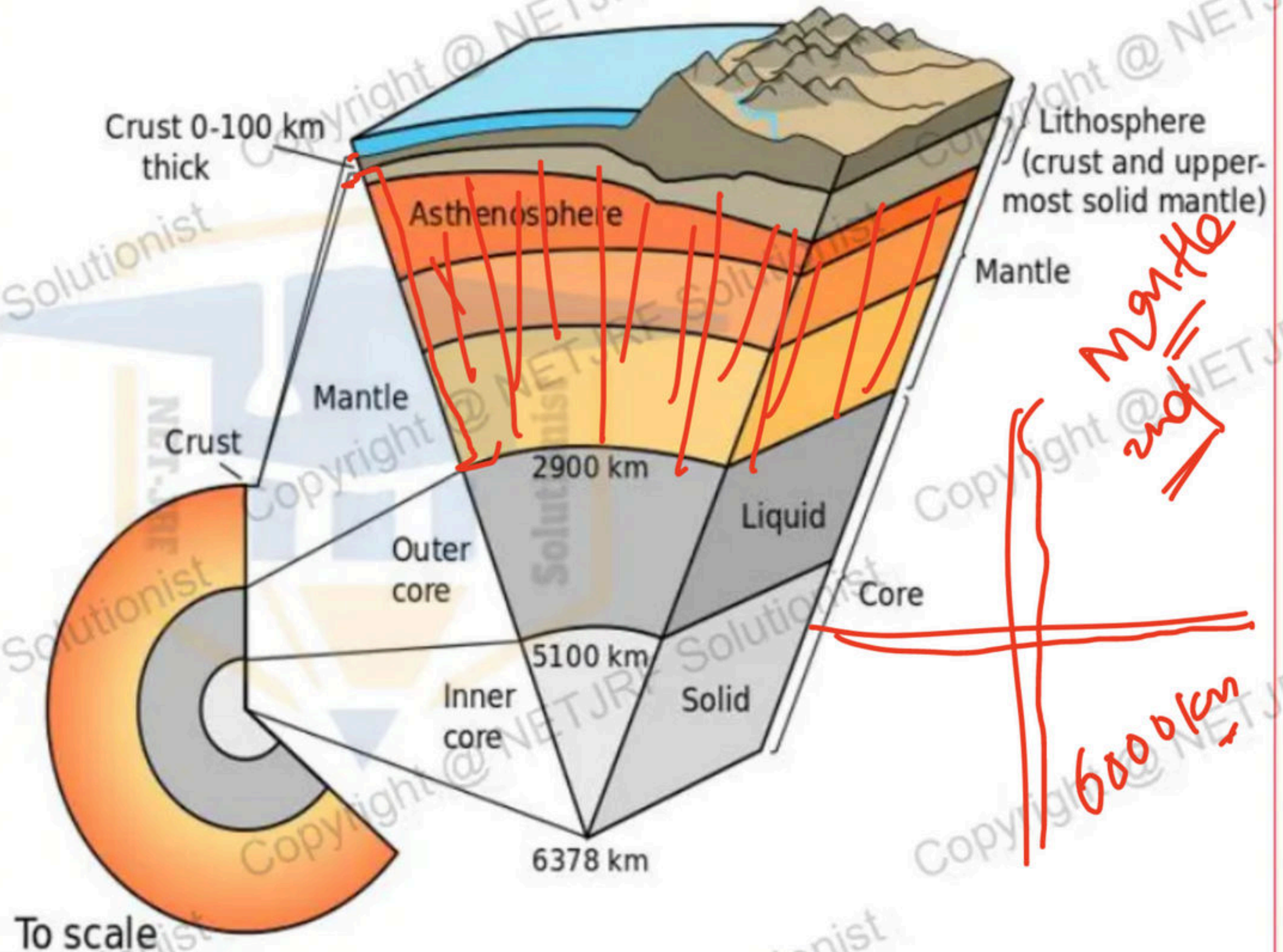
Crust  
Upper Mantle  
Lower Mantle  
Outer Core  
Inner Core



## Earth's Layers

- The structure of the earth's interior is made up of several **concentric layers**.
- Broadly three layers can be identified-

1. **Crust**
2. **Mantle**
3. **The Core**



## Earth's Layers - The Crust

- Crust is the outer thin layer with a total thickness normally between **30-50 km**.
- The thickness of the crust varies under the oceanic and continental areas.
- **Oceanic crust is thinner (5-30 km thick) as compared to the continental crust (50-70 km thick).**
- The continental crust is thicker in the areas of major mountain systems. It is as much as **70 -100 km** thick in the Himalayan region.
- It forms **0.5 - 1.0 per cent** of the earth's volume.
- The discontinuity between the hydrosphere and crust (**Upper crust – Lower crust**) is termed as the **Conrad Discontinuity**.
- **Mohorovicic (Moho) discontinuity** forms the boundary between **Crust and Asthenosphere** (Asthenosphere is a part of mantle).
- The outer covering of the crust is of sedimentary material (granitic rocks) and below that lie crystalline, igneous and metamorphic rocks which are **acidic** in nature.
- The lower layer of the crust consists of **basaltic and ultra-basic rocks**.
- The continents are composed of lighter silicates - Silica + Aluminium (also called '**sial**') while the oceans have the heavier silicates - silica + magnesium (also called '**sima**').

Unknown Layer

29

SOIL

ROCK

18/60

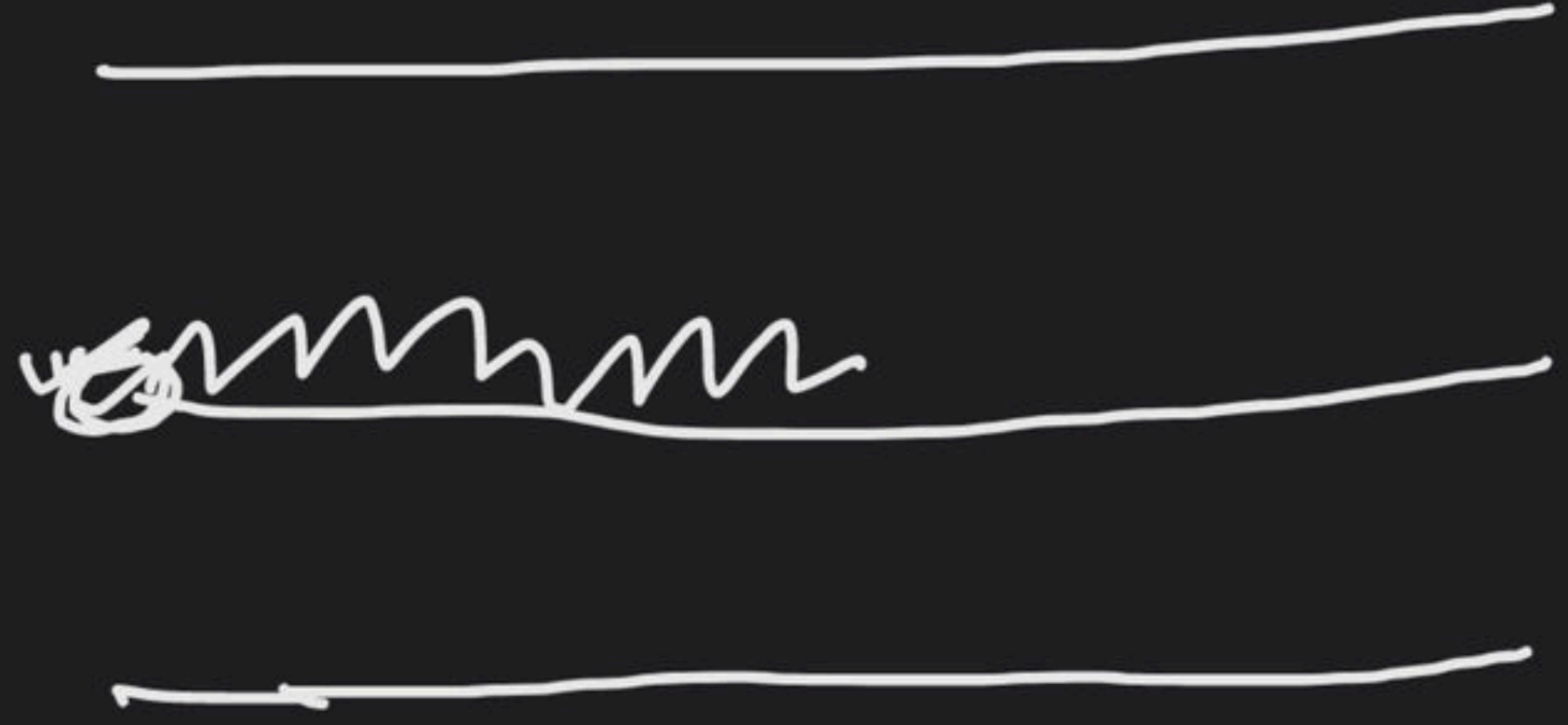
11

+

10

Time

Time

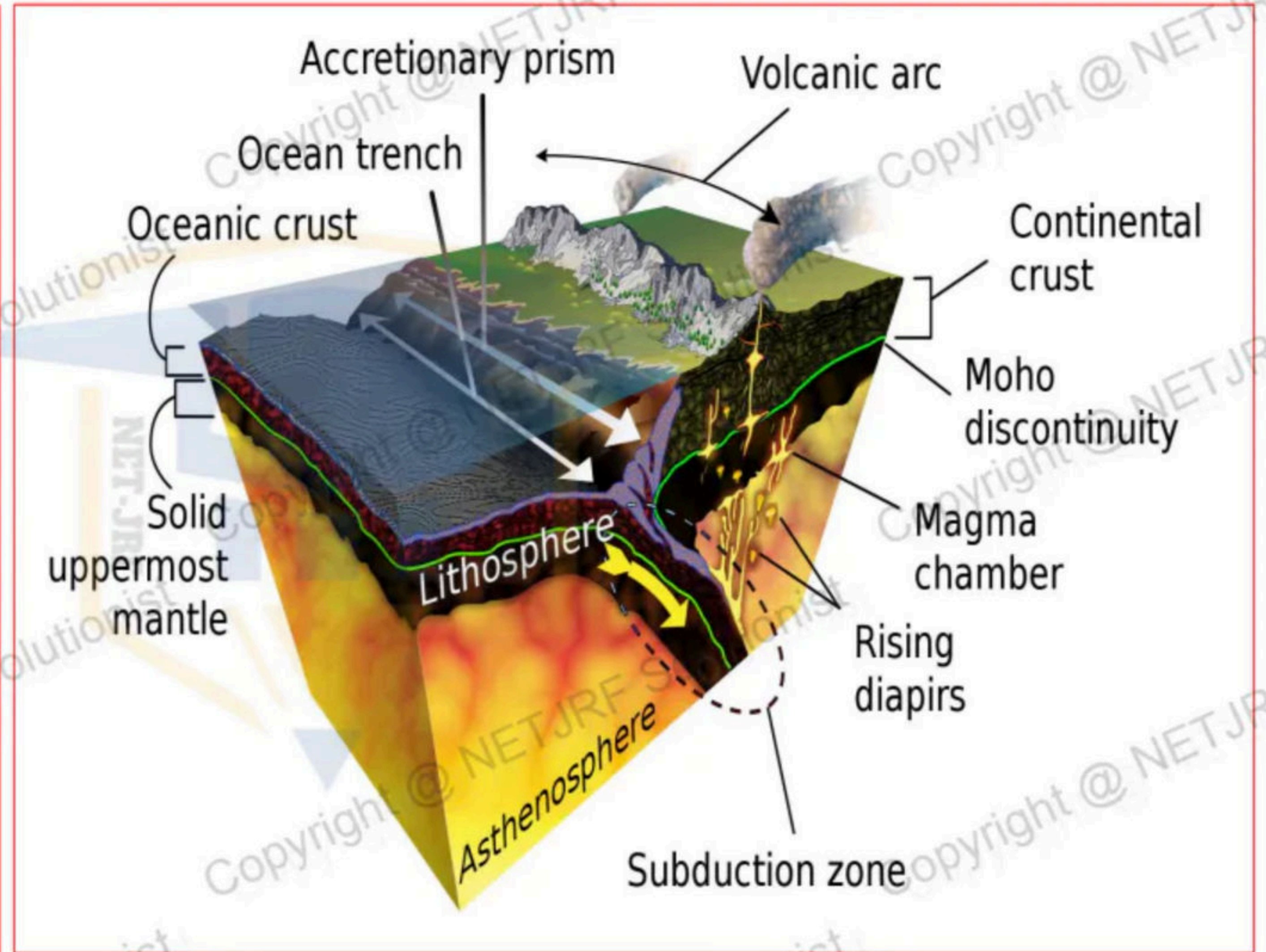


## Earth's Layers - Mantle

- The mantle extends from **Moho's discontinuity** (35 km) to a depth of **2,900 km** (Moho-Discontinuity to the outer core).
- 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.
- The density of mantle varies between 2.9 and 3.3. The density ranges from 3.3 to 5.7 in the lower part.
- It is composed of solid rock and magma. **The major constituent elements of the mantle are Silicon and Magnesium** and hence it is also termed as **SIMA**.
- It forms **84 per cent** of the earth's volume.
- **The asthenosphere is the main source of magma and it is the layer over which the lithospheric plates/continental plates move (Plate Tectonics).**
- **The discontinuity between the Upper Mantle and Lower Mantle is known as Repetti Discontinuity.**
- The portion of the mantle which is just below the lithosphere and asthenosphere, but above the core is called as **Mesosphere**.

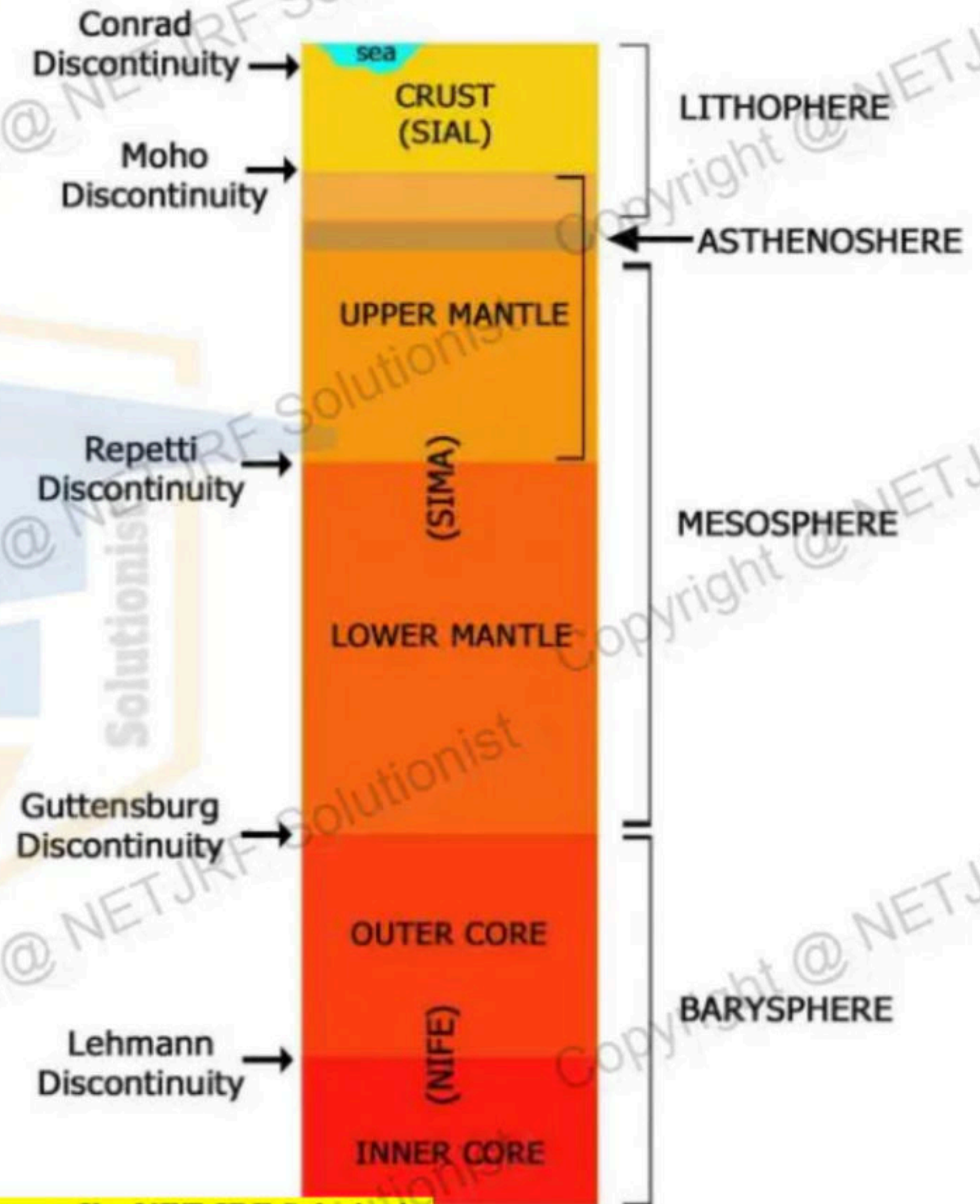
## Earth's Layers – Asthenosphere

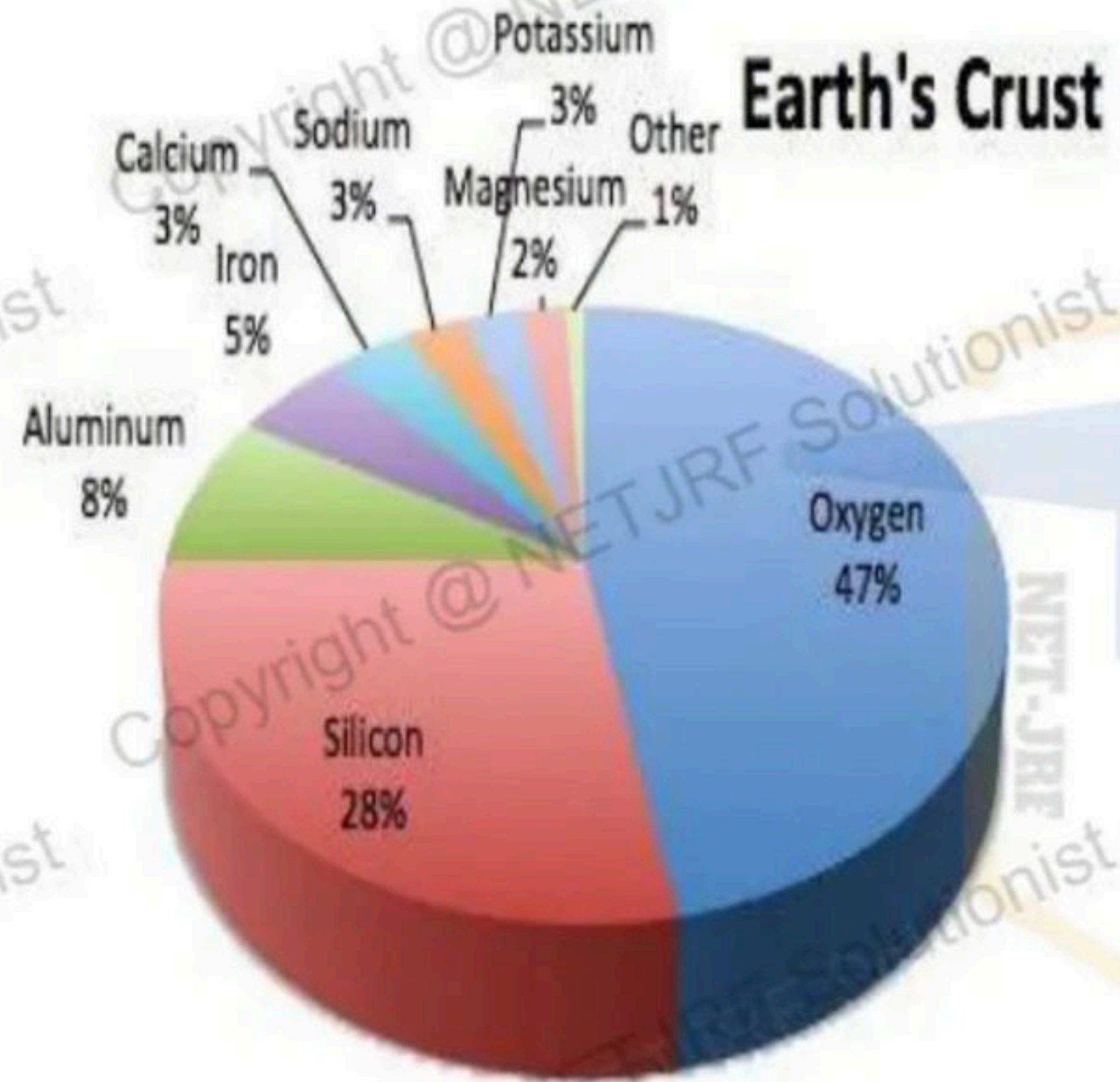
- The upper portion of the mantle is called **Asthenosphere**.
- The word "**Asthen**" means weak.
- It is considered to be extending up to **400 km**.
- It is the **main source of magma** that finds its way to the surface during volcanic eruptions. It has a density higher than the crust's.



## Earth's Layers - Core

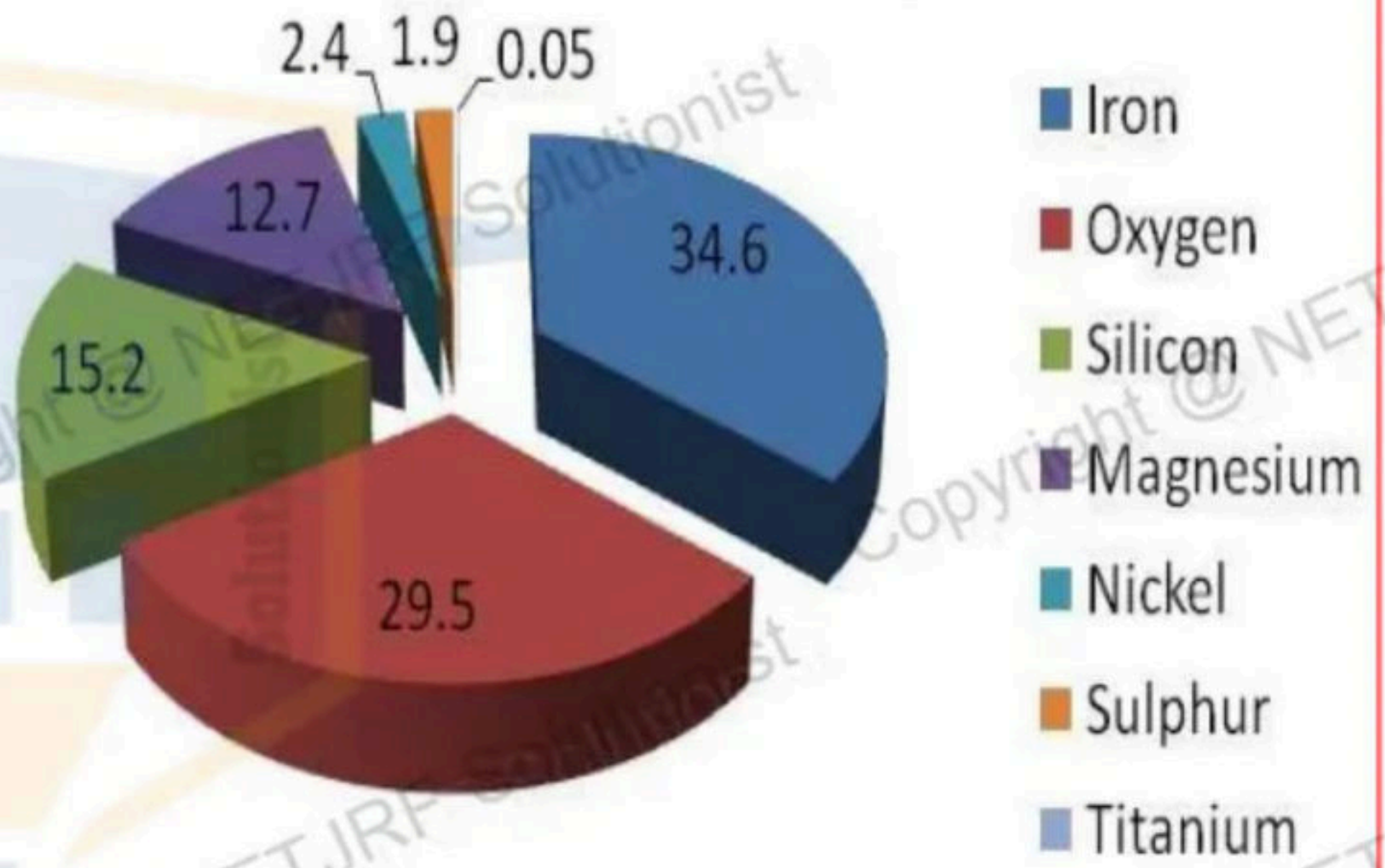
- Lies between **2900 km and 6400 km** below the earth's surface.
- Accounts for **15 per cent** of the earth's volume.
- **Gutenberg Discontinuity** - lies between the **mantle and the outer core**. Below 2900 km from earth's surface.
- The discontinuity between the **Upper Core and the Lower Core** is called as **Lehmann Discontinuity**.
- **Barysphere** is sometimes used to refer the core of the earth or sometimes the whole interior.
- Core has the heaviest mineral materials of highest density. It is composed of **Nickel and Iron (Nife)**.
- The outer core is **liquid** while the inner core is **solid**.
- A zone of mixed heavy Metals + Silicates separates the core from outer layers.





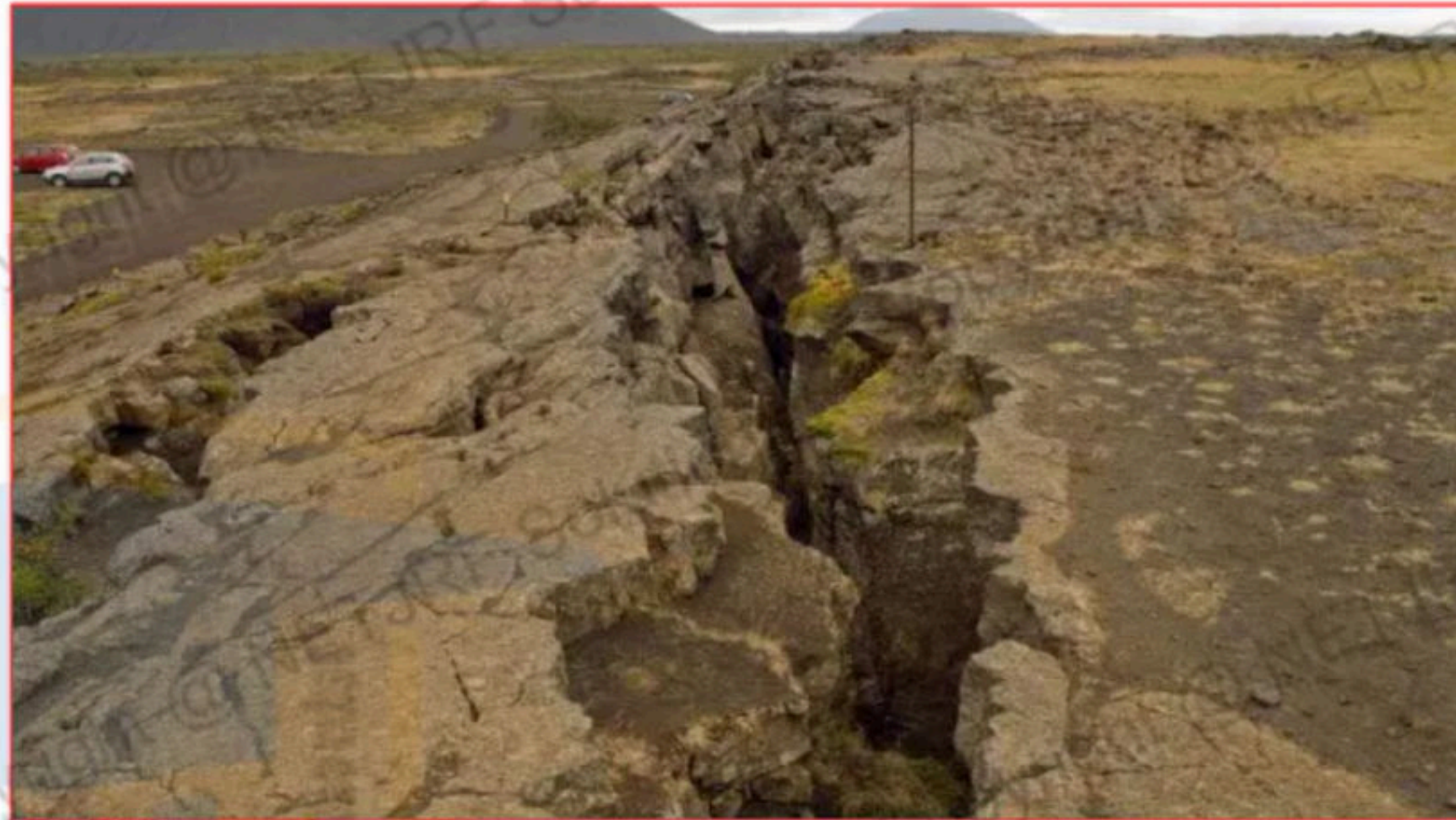
**Composition of Earth's Crust**

### Earth's Chemical Composition (%)



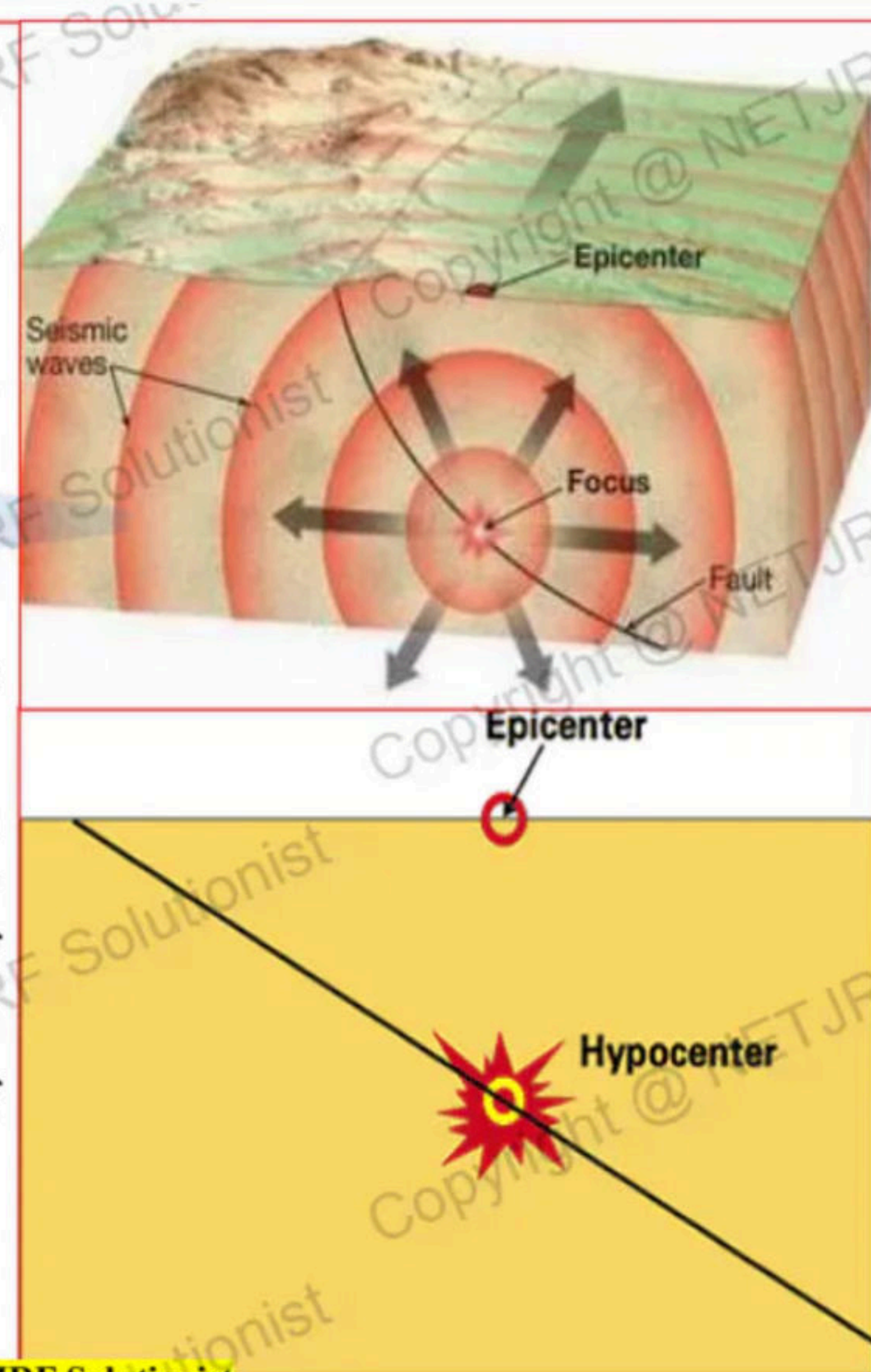
## Earthquake & Seismicity

- An earthquake is the shaking of the earth's surface, caused by the sudden movement of a part of the earth's crust.
- They result from the sudden release of energy in the Earth's crust that creates seismic waves or earthquake waves.
- About 50,000 earthquakes large enough to be noticed without the aid of instruments occur annually over the entire Earth.
- Of these, approximately 100 are of sufficient size to produce substantial damage if their centers are near areas of habitation.



## Terms associated with Earthquakes

- **Focus:** The place of origin of an earthquake inside the earth.
- **Hypocenter:** The hypocenter is the point within the earth where an earthquake rupture starts.
- **Epicenter:** Point on the earth's surface vertically above the focus. Maximum damage is caused at the epicenter.
- **Wave Velocity:** 5 to 8 km per second through the outer part of the crust but travel faster with depth.
- **Foreshocks:** Foreshocks are smaller earthquakes that precede the largest earthquake in a series, which is termed the mainshock.
- **Aftershocks:** Aftershocks are smaller quakes that follow a usually larger earthquake in the same rupture zone. They can occur up to weeks, months or even years after, depending on the size of the main shock.
- **Isoseismic Line:** A line connecting all points on the surface of the earth where the intensity is the same.



## Causes of Earthquakes

- Most earthquakes are causally related to **compressional or tensional stresses** built up at the margins of the huge moving lithospheric plates.
- The immediate cause of most shallow earthquakes is the **sudden release of stress along a fault, or fracture in the earth's crust.**
- **Sudden slipping of rock formations** along faults and fractures in the earth's crust happen due to constant change in volume and density of rocks due to intense temperature and pressure in the earth's interior.
- **Volcanic activity** also can cause an earthquake but the earthquakes of volcanic origin are generally less severe and more limited in extent than those caused by fracturing of the earth's crust.
- **Earthquakes** occur most often along geologic faults, narrow zones where rock masses move in relation to one another. The major fault lines of the world are located at the fringes of the huge tectonic plates that make up Earth's crust.
- **Plate tectonics:** Slipping of land along the fault line along, convergent, divergent and transform boundaries cause earthquakes.
- **Example:** **San Andreas Fault** is a transform fault where Pacific plate and North American plate move relative to each other causing earthquakes along the fault lines.

## Some Earthquake Inducing Human Activities

- Deep mining
- Underground nuclear tests
- Reservoir induced seismicity (RIS)
- Extraction of fossil fuels
- Artificial induction

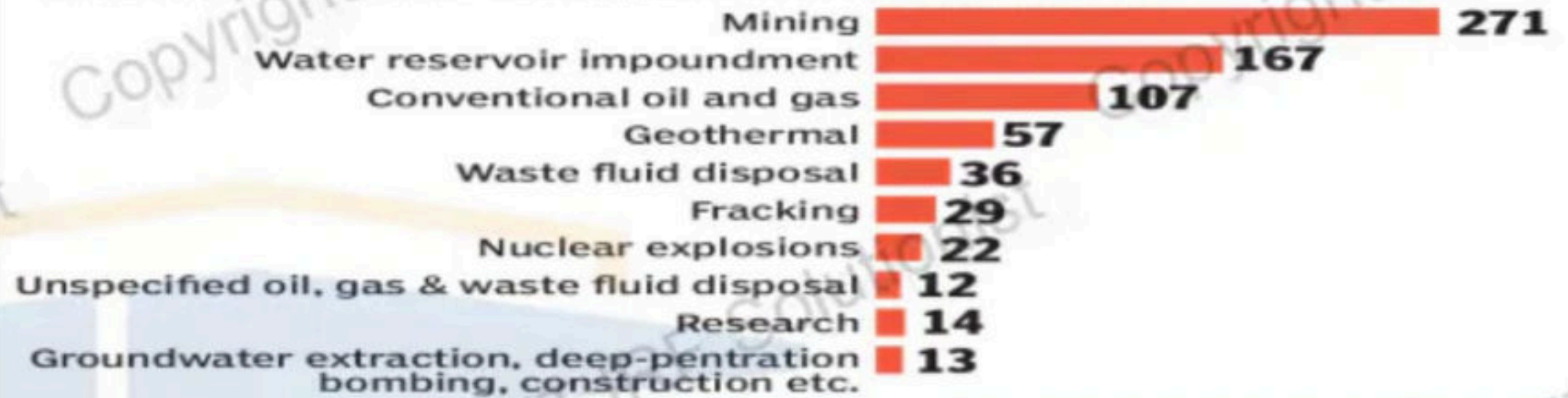
## SEISMIC FACTORS TAKEN INTO ACCOUNT

### Human-induced earthquake database (HiQuake)

No. of examples studied for human-induced seismicity from 1868-2017

**728**

### Causes of induced earthquakes & their numbers



No. of Indian examples

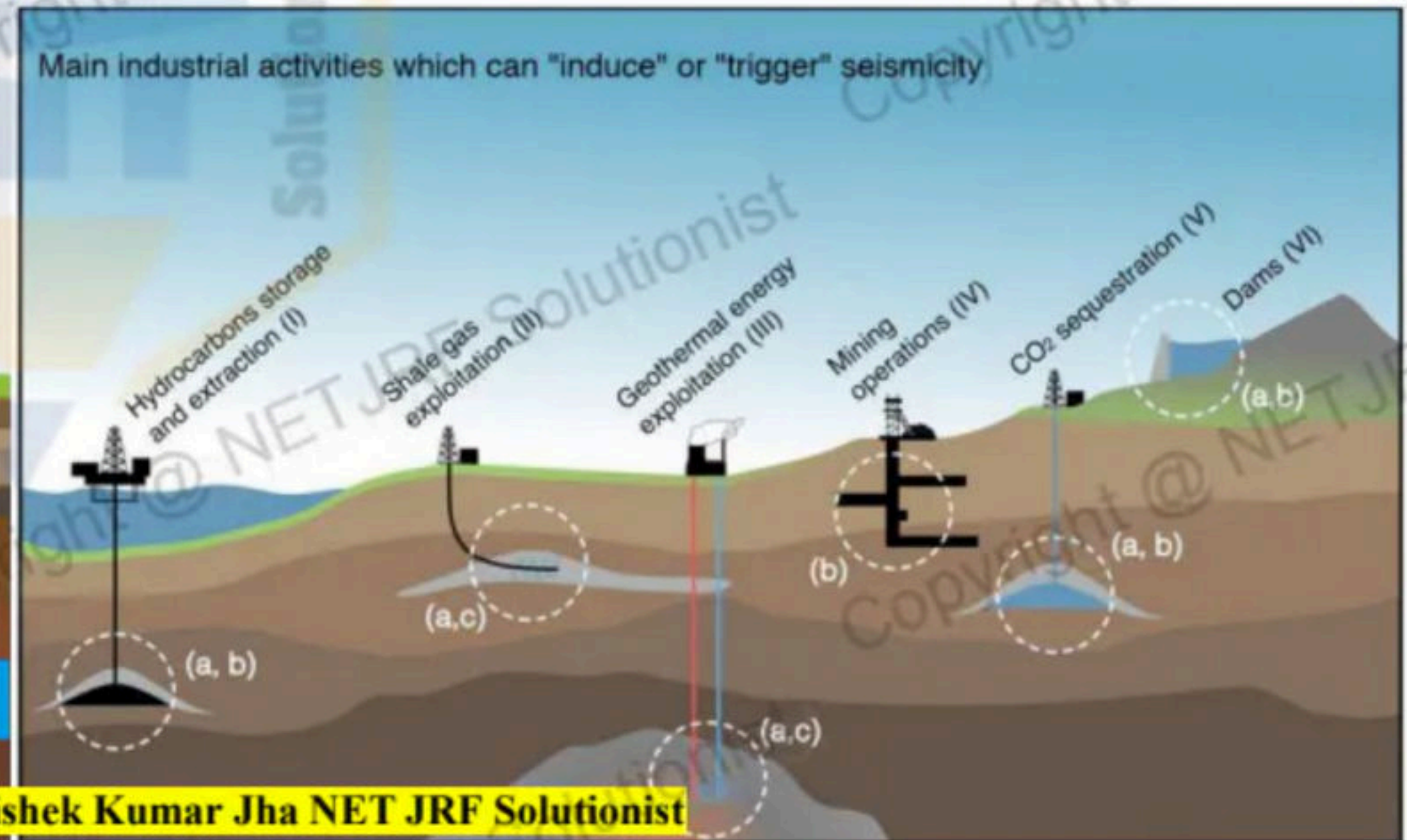
**18**

Mining  
**2**

Water reservoir impoundment  
**16**

(Source: inducedearthquakes.org and international science journal Nature)

## HOW A MAN-MADE EARTHQUAKE HAPPENS



## Seismic Waves or Earthquake Waves

- There are two categories of seismic waves known as **body and surface waves**.
- **Body waves** moves along the internal division of the Earth and further divided into two sub-types. These are **Primary and Secondary** waves designated by the capital letter **P and S**.
- **Surface waves** as the name itself indicates moves at the external division of the Earth's surface with two subtypes namely **Rayleigh and Love waves**.

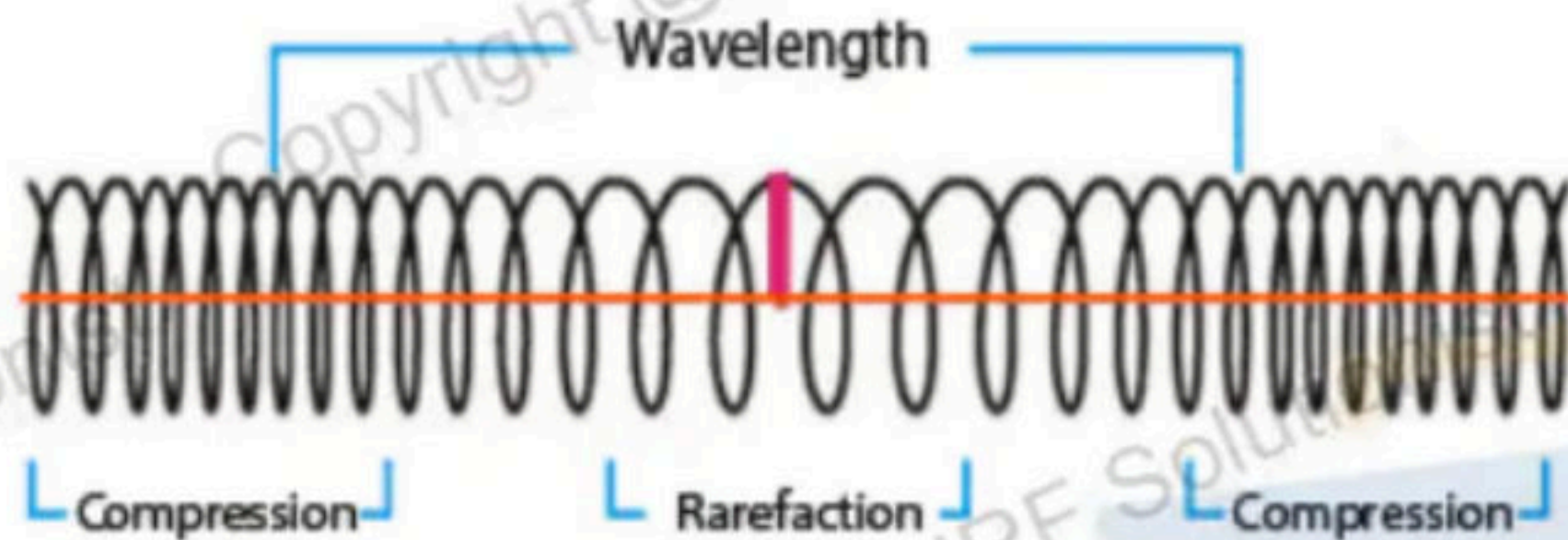
### 1. Body waves:

- Medium of motion through dominant objects is the **main characteristic feature of body waves at greater depths**. Body waves are of two types viz; **P and S waves**.
- **1. P or Primary waves** are the speediest moving at a speed of 5 kilometres per second. Also called as the **longitudinal or compressional waves and Analogous to sound waves**.
- It is basically **push and pull type waves** moving towards the direction of wave motion. This resembles to the sound produced by the strings of a musical instrument like sitar as it puts the air into motion to produce such sounds.
- P waves are able to move through all three mediums. P-waves move faster and are the **first to arrive at the surface**. These waves are of high frequency. **Velocity of P waves in Solids > Liquids > Gases**.

- **2. S or Secondary waves**, which causes vibrations at right angles in the direction of wave movement. It is less speedy than P waves as it moves at nearly 3 kilometres per second. Also called as **transverse or distortional waves** and Analogous to **water ripples**. **A secondary wave cannot pass through liquids or gases.**

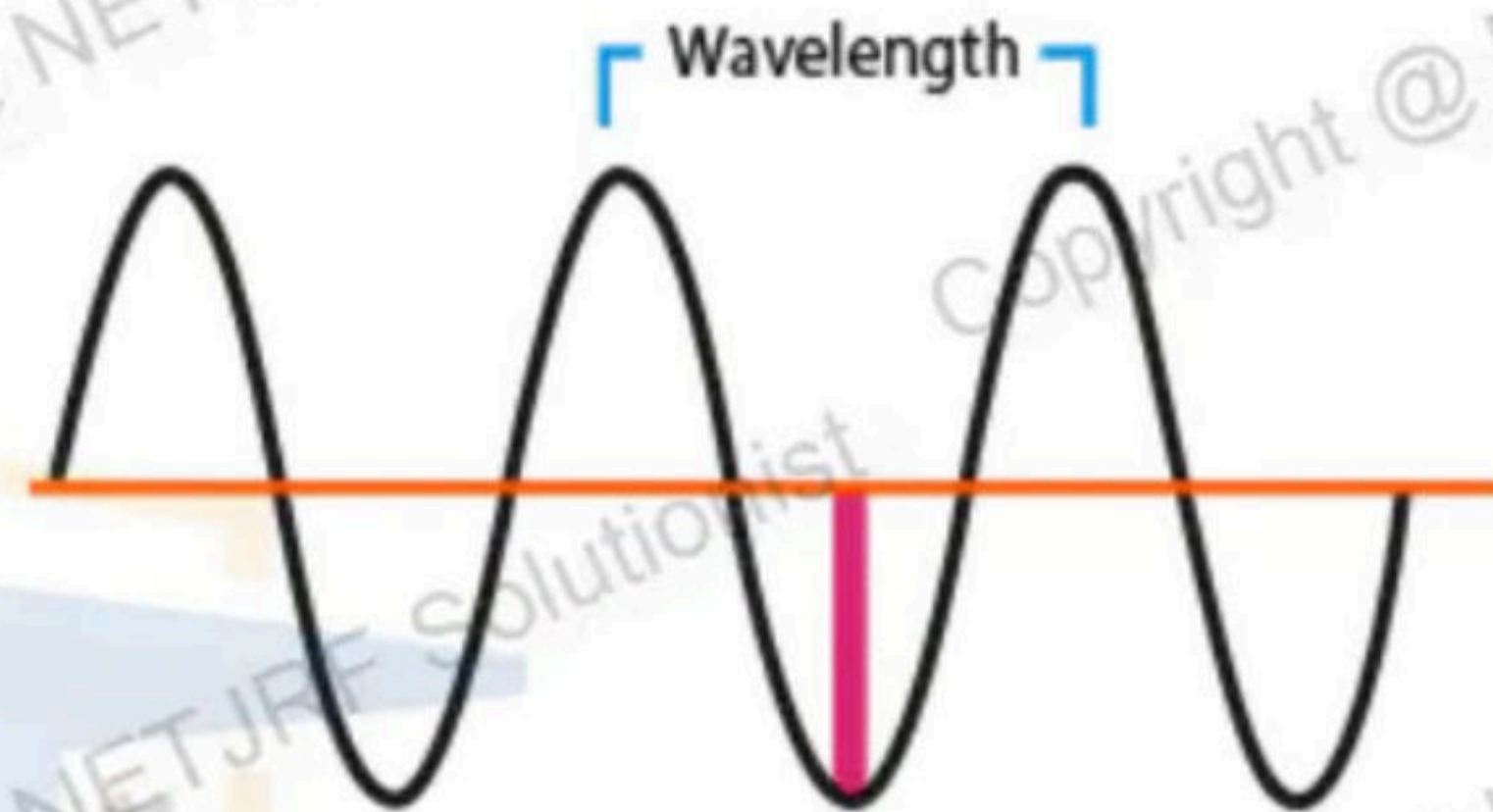
## 2. Surface waves:

- This category is characterised by complexity in motion at ground level. It makes everything upon the surface to be in motion including buildings, bridges, transmission lines and numerous man-made objects. It has two types, Rayleigh and Love waves:
  1. **Rayleigh wave** with up and down motions as like that of an electronically operated lift in a multi-storey building. Named after **Lord Rayleigh** in 1885. **Rayleigh waves** are a type of **surface acoustic wave** that travel along the surface of solids. **A Rayleigh wave is a seismic surface wave causing the ground to shake in an elliptical motion, with no transverse, or perpendicular, motion.**
  2. **Love wave** also known as **Q waves** (Quer: German for lateral) **named after Augustus Edward Hough Love**. **A Love wave is a surface wave having a horizontal motion that is transverse (or perpendicular) to the direction the wave is traveling.** It is characterised by side to side motion resembling to that of a wave generated by a swiftly flowing perennial river system. Former type is considered more **fatal** than later as it carries the potential to damage the very base of man-made infrastructural amenities. **“L” waves are the Most Destructive. Recorded last on the seismograph.**



## LONGITUDINAL WAVE

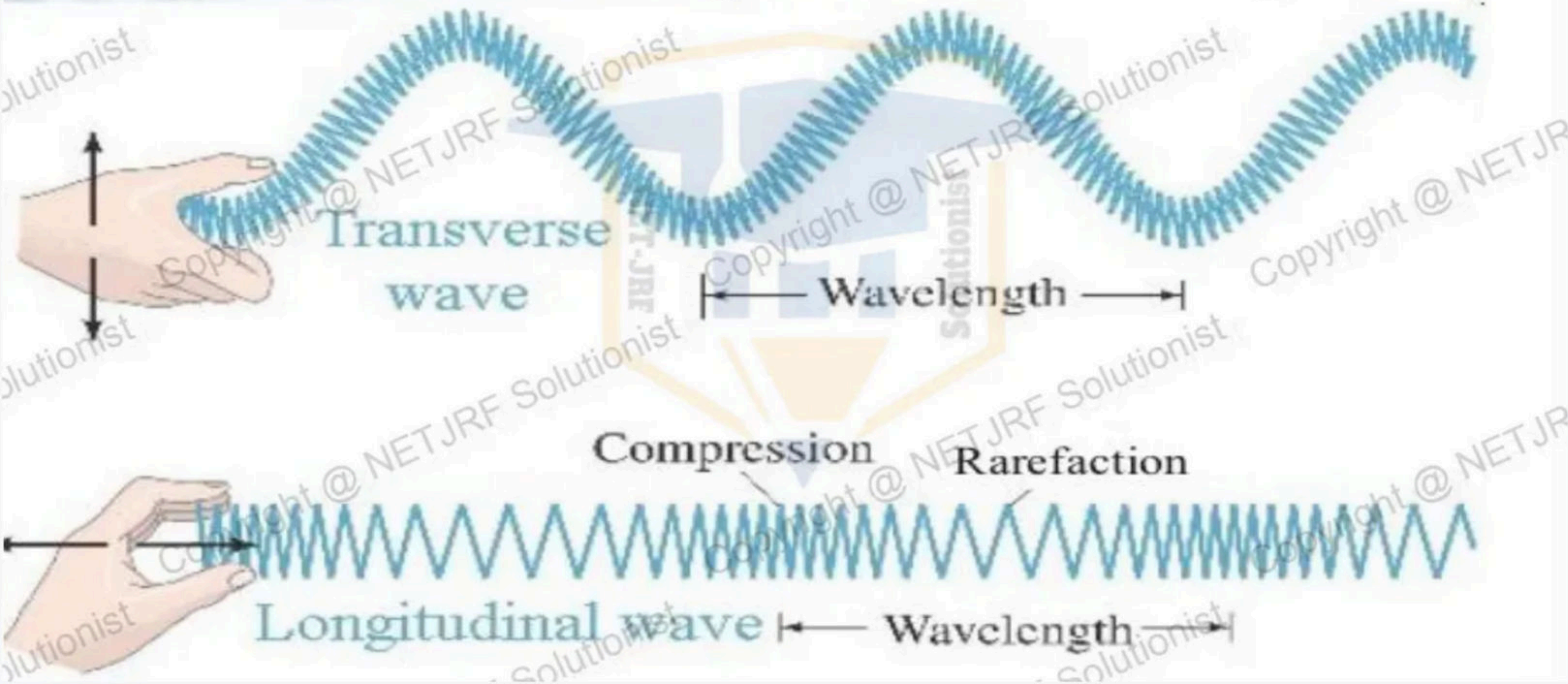
Longitudinal waves are those waves in which the particles of the medium move parallel to the propagation of the wave. For example, sound waves are longitudinal waves



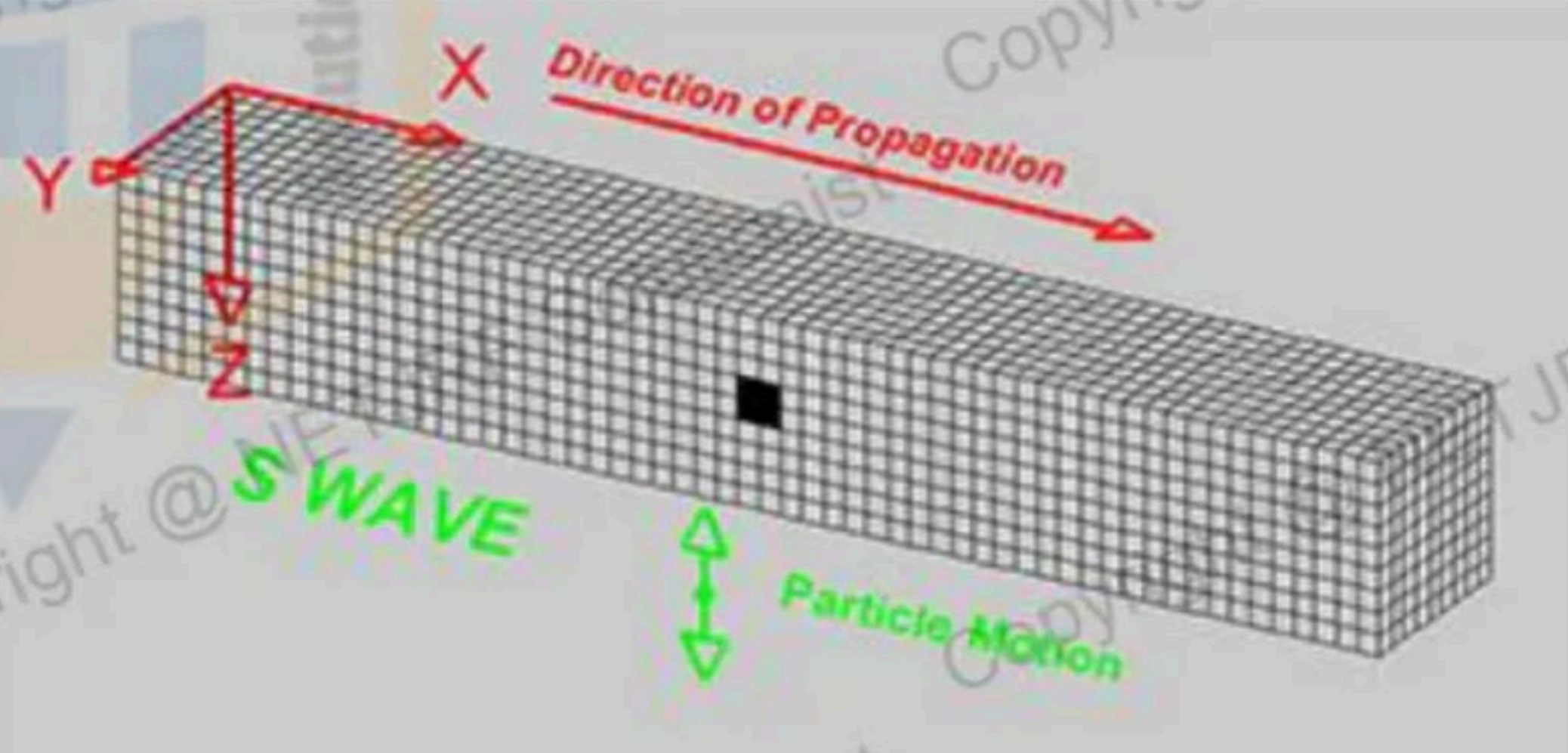
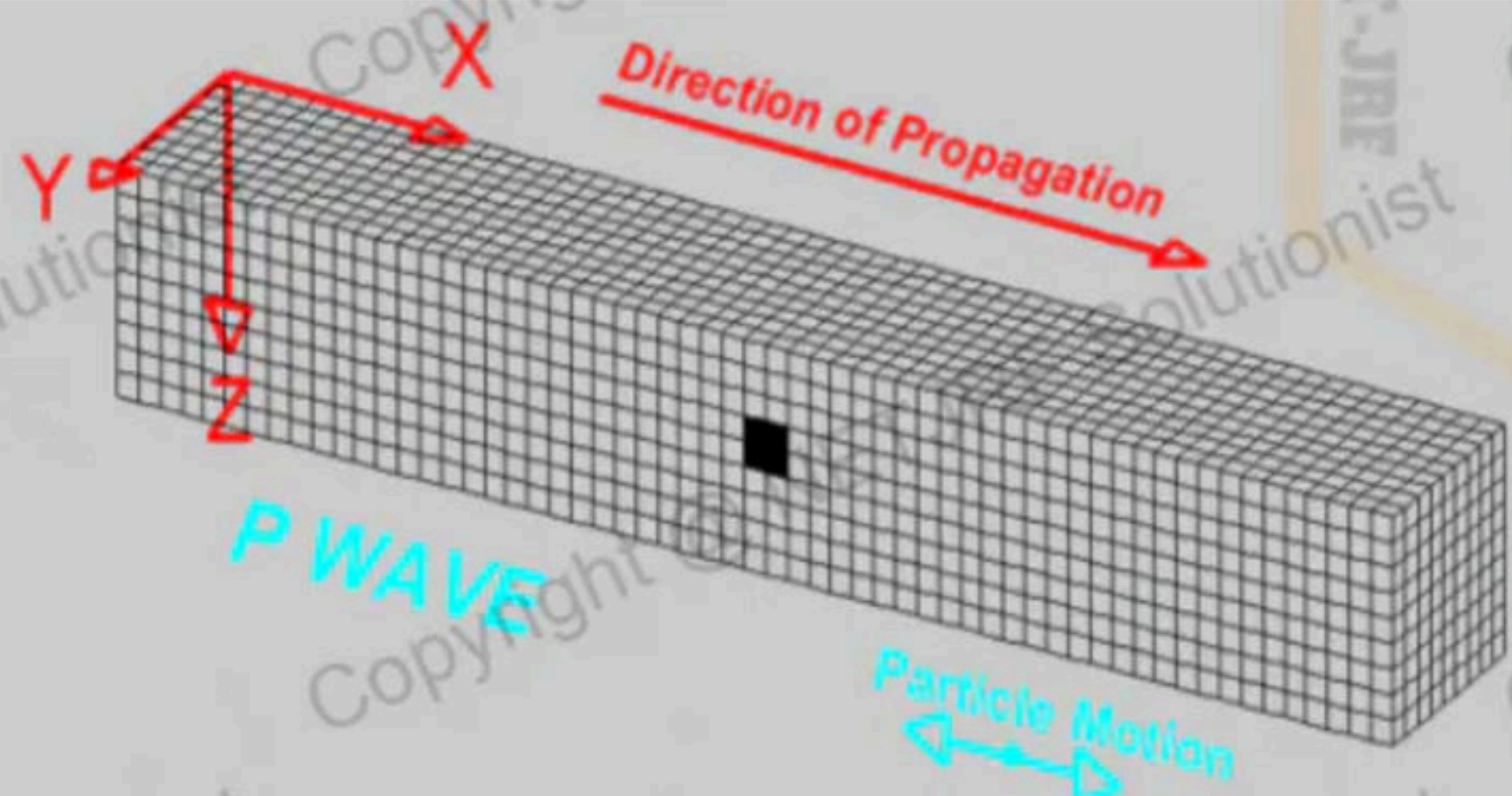
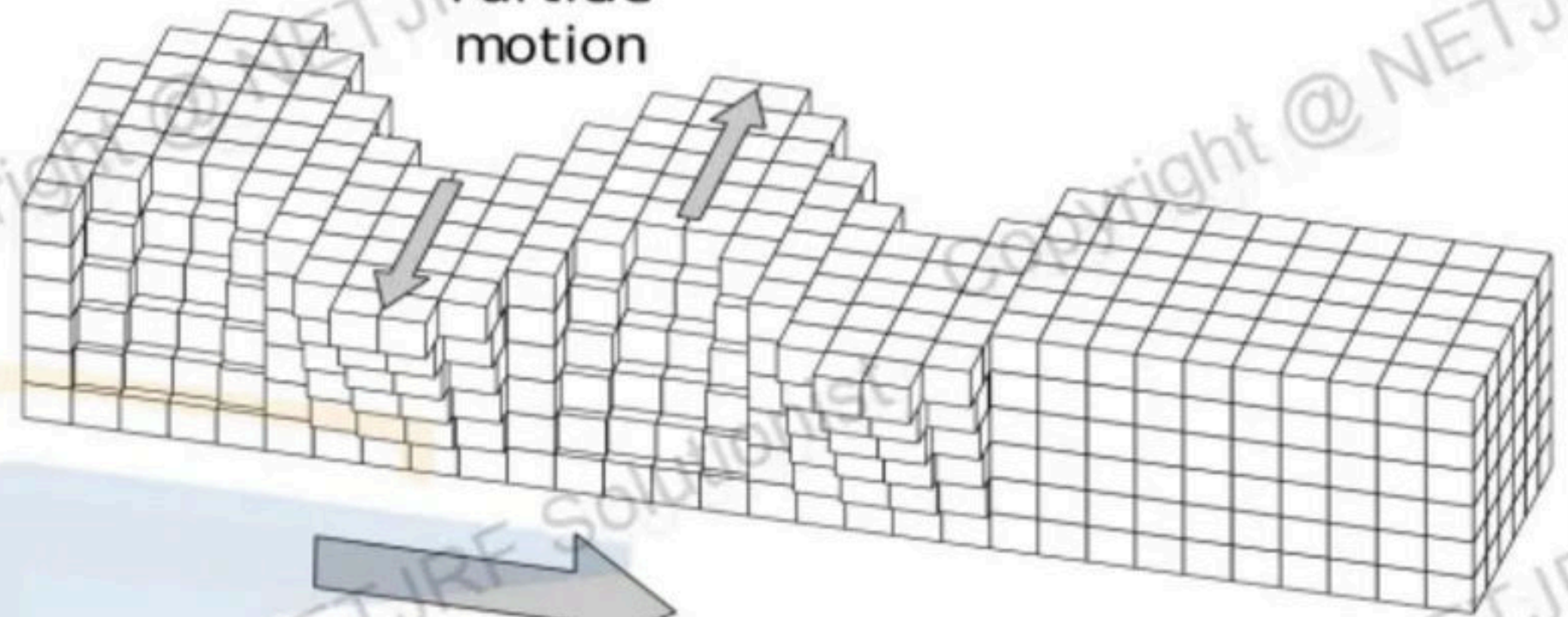
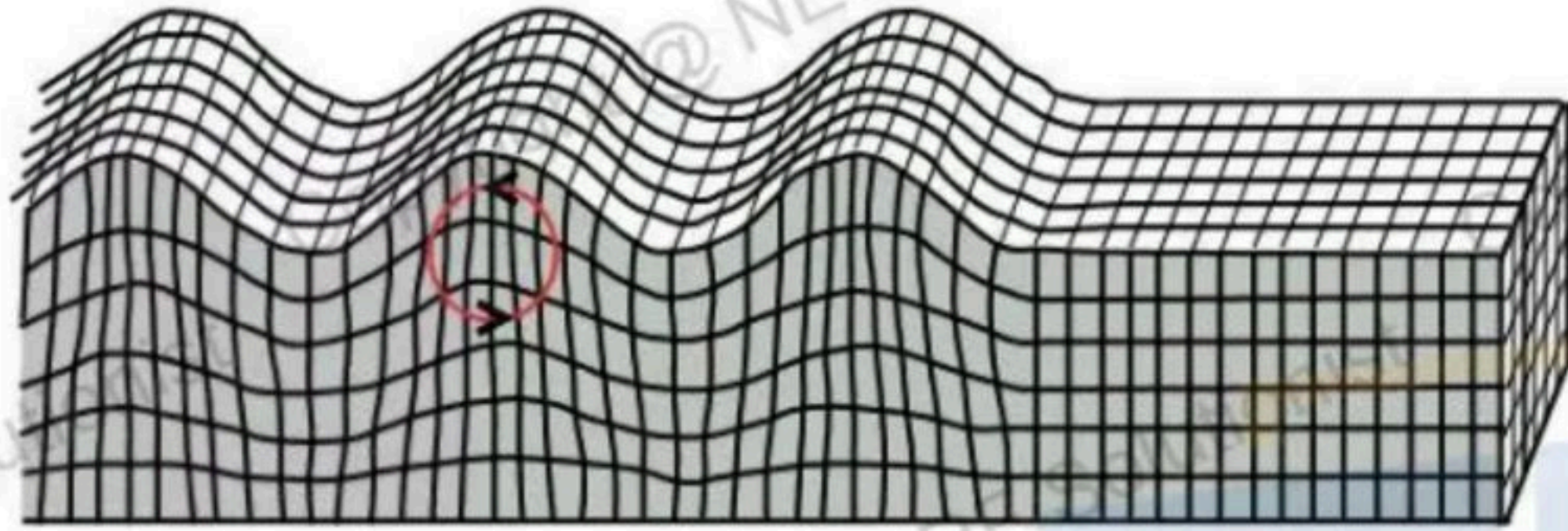
## TRANSVERSE WAVE

Transverse waves are those waves in which the particles of the medium move perpendicular to the direction of the propagation of the wave. For example, ripples formed on the surface of the water, is a transverse wave.

# Transverse & Longitudinal Waves



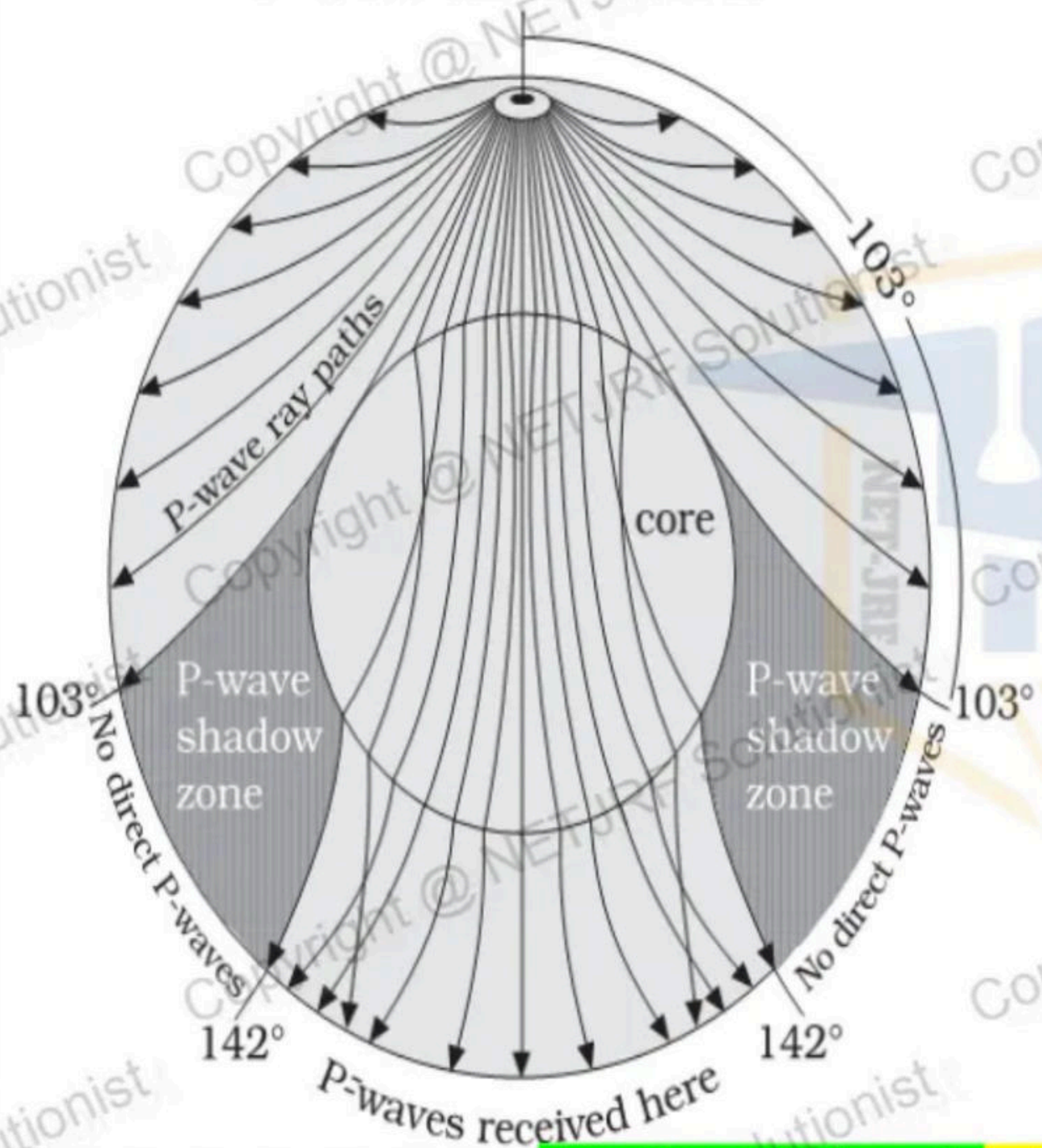
# Rayleigh Wave



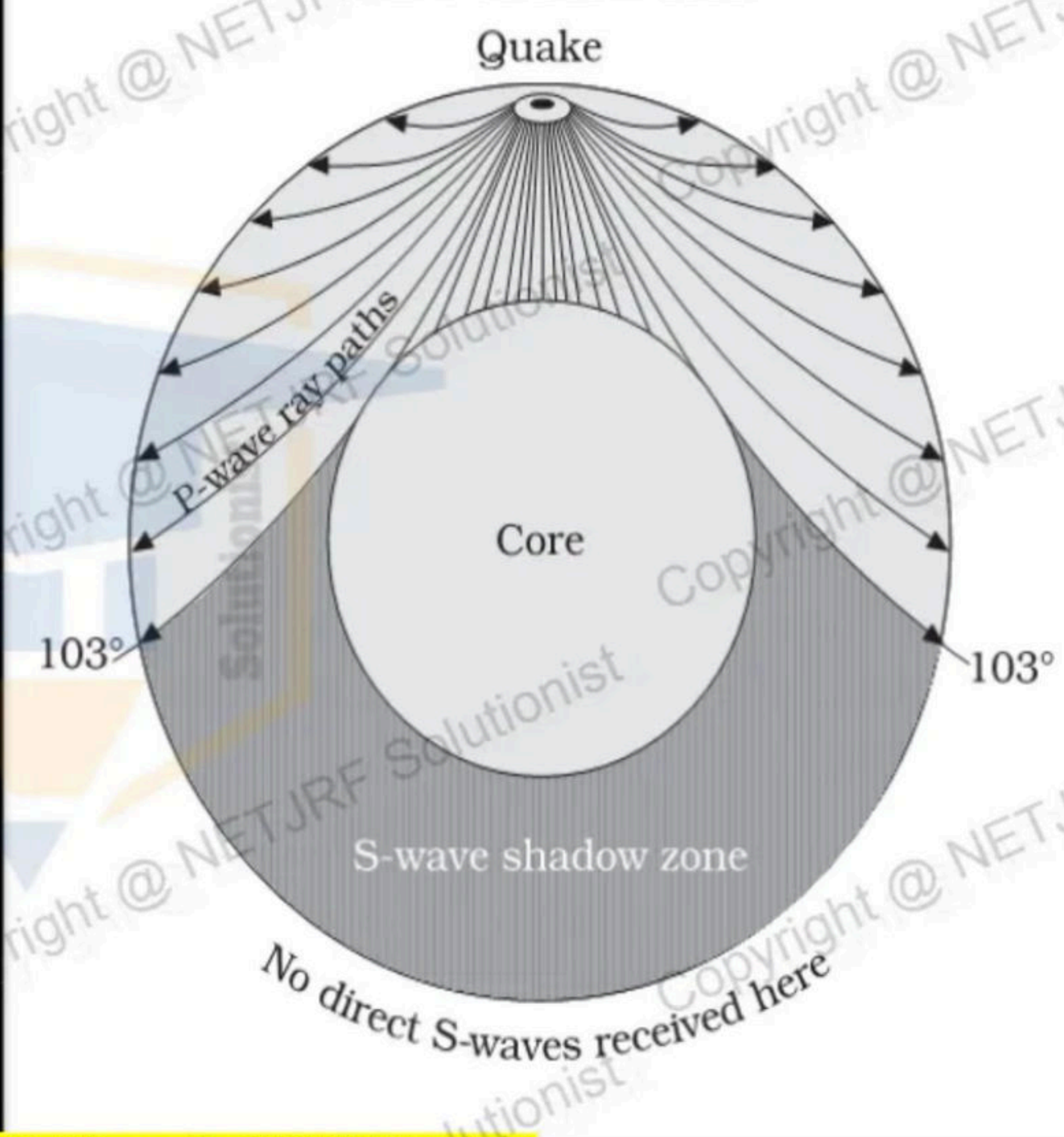
## The emergence of Shadow Zone of P-waves and S-waves

- S-waves do not travel through liquids (they are **attenuated**).
- The entire zone beyond  $103^\circ$  does not receive S-waves, and hence this zone is identified as the shadow zone of S-waves. This observation led to the discovery of the **liquid outer core**.
- The shadow zone of P-waves appears as a band around the earth between  $103^\circ$  and  $142^\circ$  away from the epicentre.
- This is because P-waves are refracted when they pass through the transition between the semisolid mantle and the liquid outer core.
- However, the seismographs located beyond  $142^\circ$  from the epicentre, record the arrival of P-waves, but not that of S-waves. This gives clues about the **solid inner core**.
- Thus, a zone between  $103^\circ$  and  $142^\circ$  from epicentre was identified as the **shadow zone for both the types of waves**.

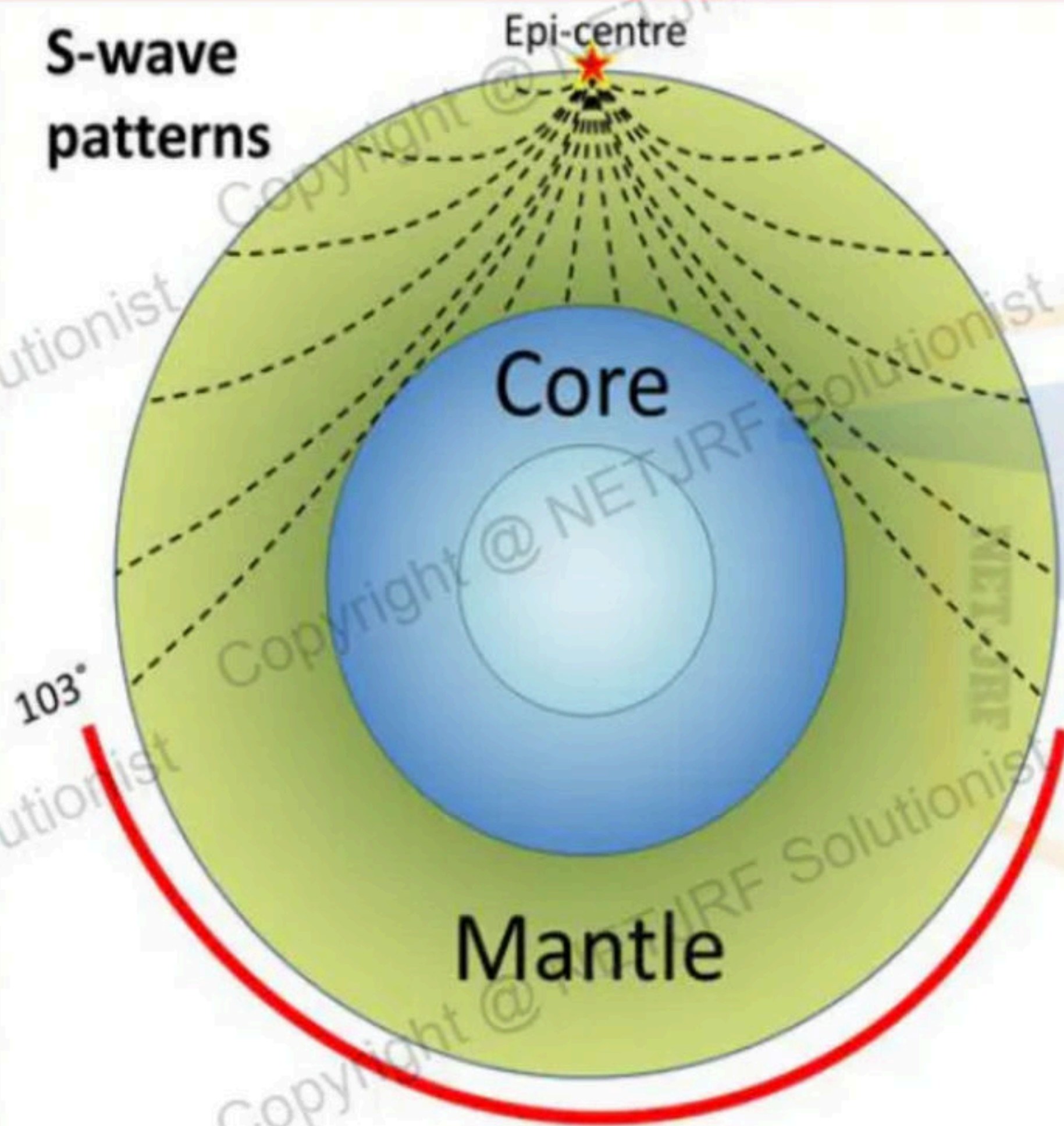
### P-wave shadow zone



### S-wave shadow zone

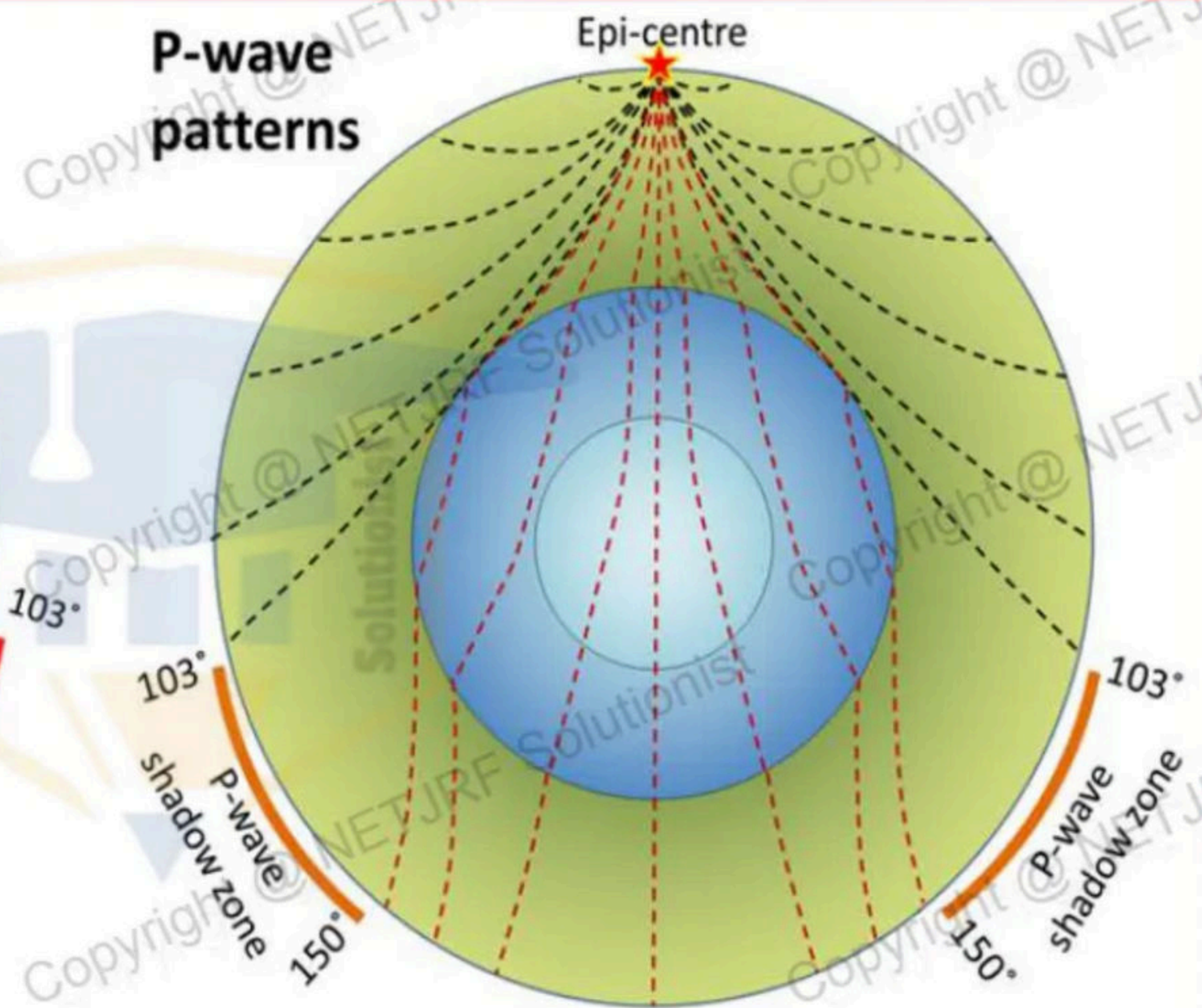


# S-wave patterns



S-wave shadow zone

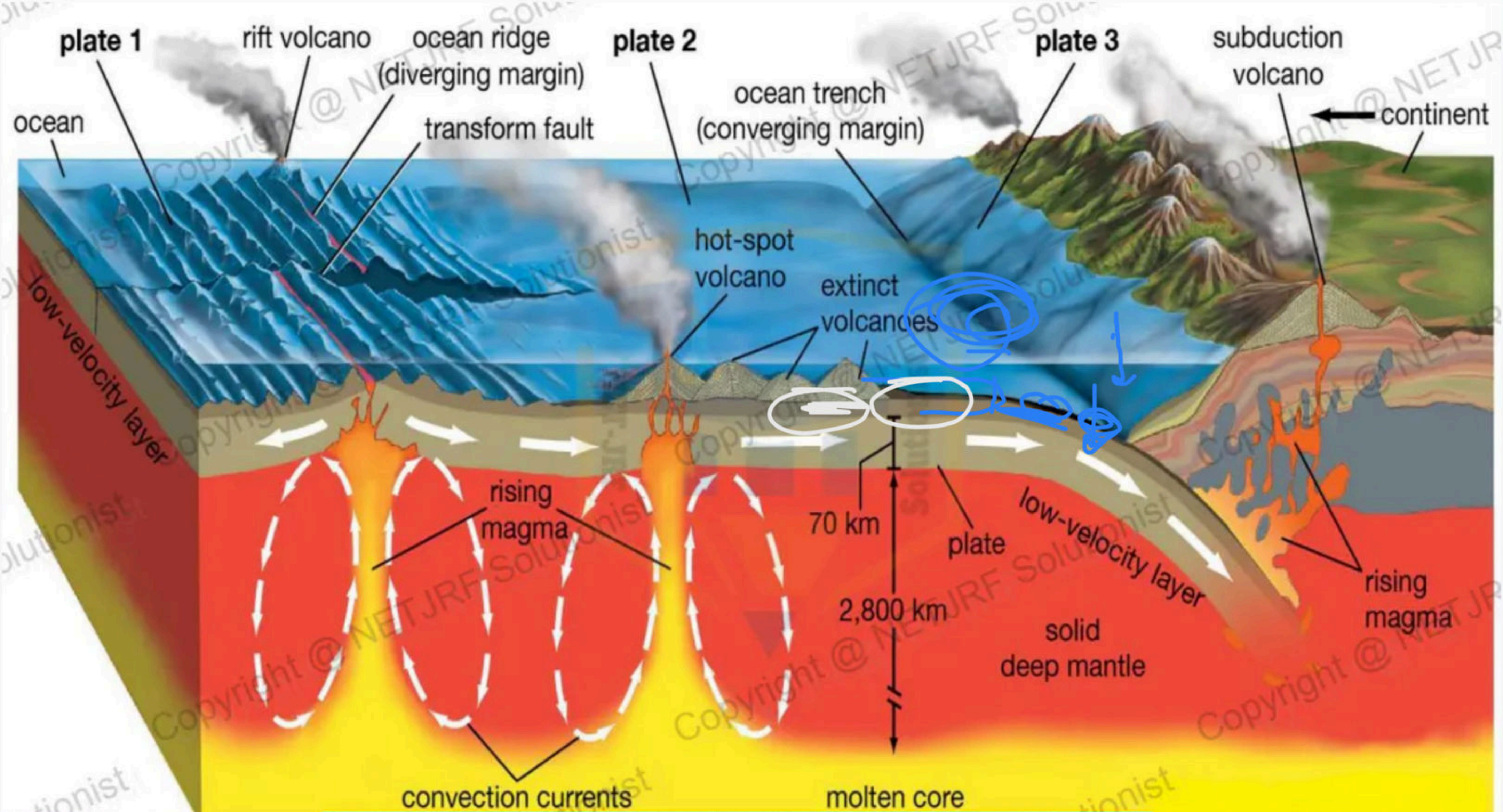
# P-wave patterns



P-waves that passed through the core

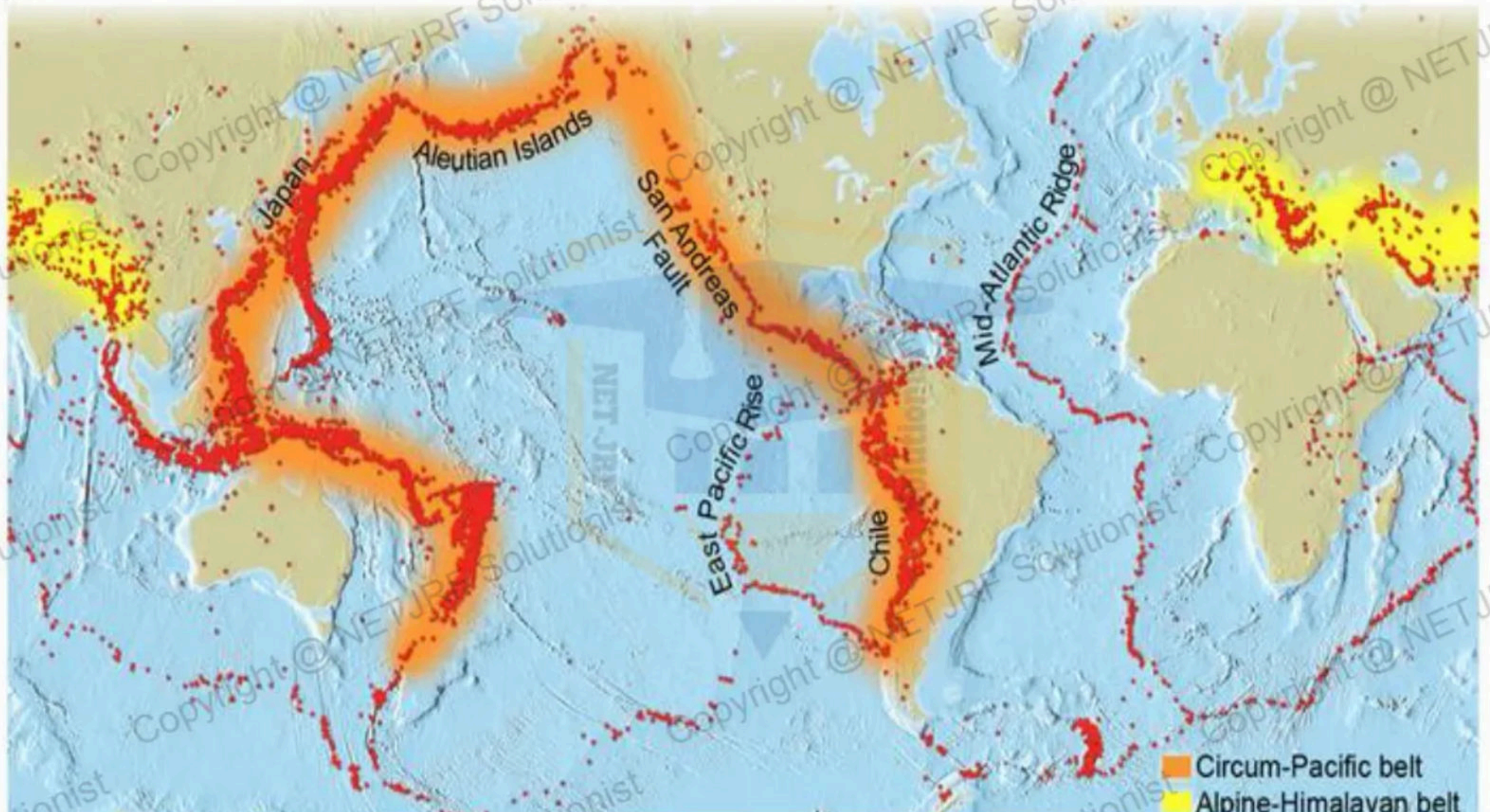
## Earthquakes based on the depth of Focus

- Benioff zone is a zone of subduction along which earthquakes are common. **Wadati-Benioff zone** is a zone of seismicity corresponding with the down-going slab in a subduction zone (Convergent Boundary).
- Differential motion along the zone produces numerous earthquakes.
- 1. **Shallow Focus Earthquakes** (most common at submarine ridges. Hardly felt). Shallow focus earthquakes are called **crustal earthquakes** as they exist in the earth's crustal layer. Shallow-focus earthquakes occur at depths less than 70 km. Shallow focus earthquakes are of smaller magnitudes, of a range 1 to 5.
- 2. **Deep Focus Earthquakes** (Occurs at trenches –Very powerful. Japan lies along trench line. Hence it faces devastating earthquakes **convergent boundary**). Deep focus earthquakes are known as **intra plate earthquakes**, as they are triggered off by collision between plates. **Deep-focus earthquakes occur at greater focal depths of 300 – 700 km.** Deep focus earthquakes are of higher magnitudes, 6 to 8 or more.
- **Shallow earthquakes** have a focus 0 – 70 km deep.
- **Intermediate earthquakes** have a focus 70 – 300 km deep.
- **Deep earthquakes** have a focus 300 – 700 km deep.



## Distribution of Earthquakes

- Earth's major earthquakes occur mainly in belts coinciding with the margins of tectonic plates. **The most important earthquake belt is the Circum-Pacific Belt**, which affects many populated coastal regions around the Pacific Ocean. for example, those of New Zealand, New Guinea, Japan, the Aleutian Islands, Alaska, and the western coasts of North and South America.
- The seismic activity is by no means uniform throughout the belt, and there are a number of branches at various points. Because at many places the Circum-Pacific Belt is associated with volcanic activity, it has been popularly dubbed the **"Pacific Ring of Fire"** The Pacific Ring of Fire accounts for about **68 per cent of all earthquakes.**
- **A second belt, known as the Alpine Belt (Himalayas and Alps).** The energy released in earthquakes from this belt is about 15 percent of the world total.
- The mid-world mountain belt (Alpine Belt) extends parallel to the equator from Mexico across the Atlantic Ocean, the Mediterranean Sea from Alpine-Caucasus ranges' to the Caspian, Himalayan mountains and the adjoining lands. This zone has folded mountains, large depressions and active volcanoes.
- There also are striking connected belts of seismic activity, mainly along oceanic ridges - including those in the Arctic Ocean, the Atlantic Ocean, and the western Indian Ocean—and along the **Rift valleys of East Africa.**



## Reading: Magnitude versus Intensity

- Magnitude and Intensity measure different characteristics of earthquakes.
- **Magnitude** is determined from measurements on seismographs. **Magnitude measures the energy released at the source of the earthquake.**
- **Intensity:** The effect of an earthquake on the Earth's surface is called the intensity. **Intensity** measures the strength of shaking produced by the earthquake at a certain location.
- Intensity is determined from effects on people, human structures, and the natural environment.

<b>Magnitude Richter scale</b>	<b>Average number per year</b>	<b>Modified Mercalli Intensity</b>	<b>Description</b>
0 – 1.9	>1 million	—	Micro – not felt
2.0 – 2.9	>1 million	I	Minor – rarely felt
3.0 – 3.9	about 100,000	II – III	Minor – noticed by a few people
4.0 – 4.9	about 10,000	IV – V	Light – felt by many people, minor damage possible
5.0 – 5.9	about 1,000	VI – VII	Moderate – felt by most people, possible broken plaster and chimneys
6.0 – 6.9	about 130	VII – IX	Strong – damage variable depending on building construction and substrate
7.0 – 7.9	about 15	IX – X	Major – extensive damage, some buildings destroyed
8.0 – 8.9	about 1	X – XII	Great – extensive damage over broad areas, many buildings destroyed
9.0 and above	< 1	XI – XII	Great – extensive damage over broad areas, most buildings destroyed

Intensity	Shaking	Description/Damage
I	Not felt	Not felt except by a very few under especially favorable conditions.
II	Weak	Felt only by a few persons at rest, especially on upper floors of buildings.
III	Weak	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV	Light	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Moderate	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Strong	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Very strong	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII	Severe	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	Violent	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Extreme	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

# Magnitude vs. Intensity

## INTENSITY

measures the shaking in a certain location.

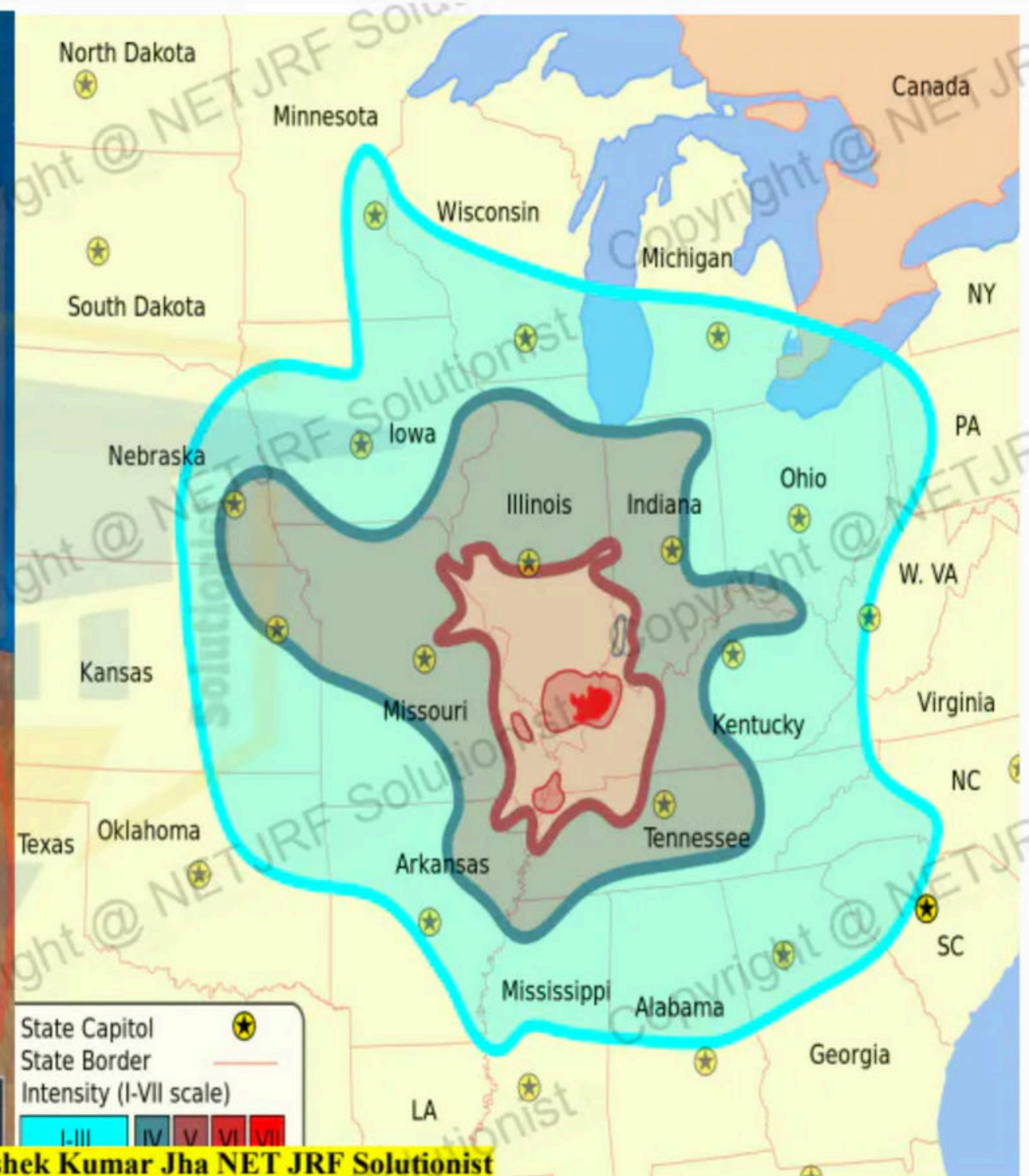
Earthquakes that are shallow and near urban areas can be greatly felt even if they are weak.



## MAGNITUDE

measures the energy released at the source of the earthquake.

Earthquakes that are small in magnitude and far from urban areas were barely felt, but are recorded in seismographs.



## Measurement of Earthquakes

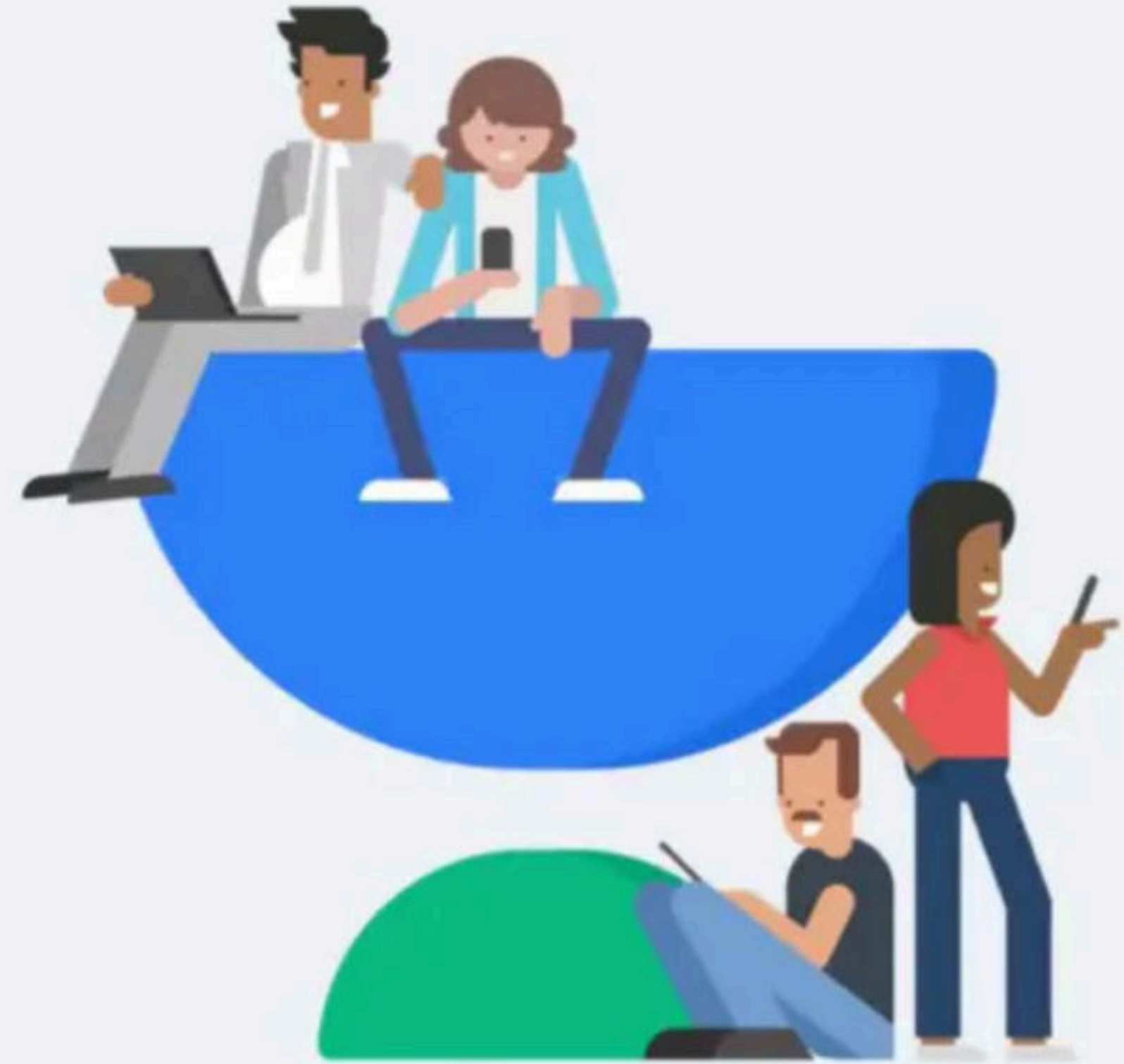
- The earthquake events are scaled either according to the magnitude or intensity of the shock.

1. **Richter scale** - 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.
2. **Mercalli scale** - 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.



We hope it was  
a helpful session!

Thank you for  
your time



**Please Give Your Feedback After The Session**