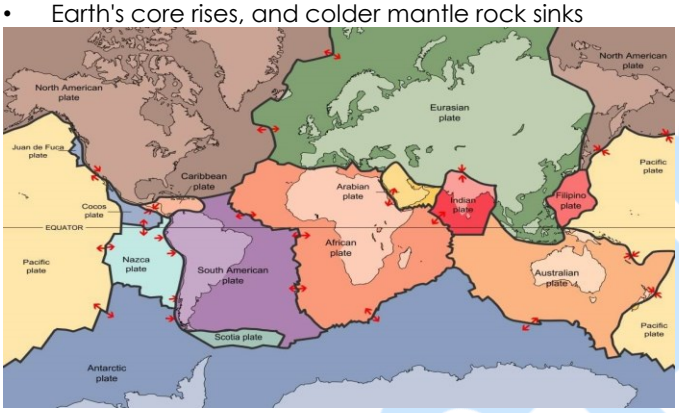
PLATE TECTONICS, ENDOGENIC FORCES & EARTHQUAKES

PLATE TECTONICS

WHAT IS PLATE TECTONICS?

- Plate tectonics is the theory that Earth's outer shell is divided into several plates that glide over the mantle/ **asthenosphere**
- These plates are so big that they can consist a whole continent or ocean or both on it.
- Plates move horizontally over the **asthenosphere** as rigid units.
- While a tectonic plate is a rigid lithospheric slab, plate tectonics is a collective term for evolution, nature and motion, deformation, the interaction of plate margins and resultant landforms.
- Continuous movements and interaction of the plates create different landforms. It is called Plate tectonics
- The driving force behind plate tectonics is convection in the mantle. Hot material near
- Earth's core rises, and colder mantle rock sinks



HOW MANY PLATES ARE THERE?

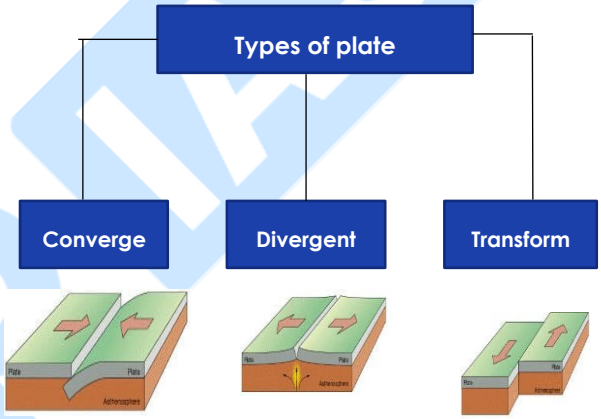
MAJOR PLATES

The major plates are as follows:

1. Antarctica and the surrounding oceanic plate
2. North American (with western Atlantic floor separated from the South American plate along the Caribbean islands) plate
3. South American (with western Atlantic floor separated from the North American plate along the Caribbean islands) plate
4. Pacific plate
5. (v) India-Australia-New Zealand plate
6. (vi) Africa with the eastern Atlantic floor plate
7. Eurasia and the adjacent oceanic plate.

MINOR PLATES

1. **Cocos plate**: Between Central America and Pacific plate
2. **Nazca plate:** Between South America and Pacific plate
3. **Arabian plate:** Mostly the Saudi Arabian landmass
4. **Philippine plate:** Between the Asiatic and Pacific plate
5. **Caroline plate:** Between the Philippine and Indian plate (North of New Guinea)
6. **Fuji plate**: North-east of Australia.
7. **Turkish** plate
8. **Aegean plate** (Mediterranean region)
9. **Caribbean** plate
10. **Juan de Fuca** plate (between Pacific and North American plates)
11. **Iranian** plate



CONVERGENCE

- Convergence in plate tectonics refers to the process where two tectonic plates move towards each other and interact.

Process Details:

- **Subduction**: One of the key features of convergent plate boundaries where an oceanic plate sinks beneath another plate into the mantle, creating a subduction zone.
- **Collision**: This occurs when two plates collide, which can lead to the formation of mountain ranges.
- **Oceanic Plate**: Often the plate that is subducted due to its higher density compared to continental plates.
- **Trenches**: Deep underwater troughs created at the site where the oceanic plate begins its descent into the mantle.

Characteristics:

- **Zone of Subduction**: Characterized by the sinking of the oceanic plate and the overriding of the other plate, often leading to volcanic activity.
- **Softer Asthenosphere**: The semi-fluid layer of the mantle on which tectonic plates float; subducted plates move towards this layer.

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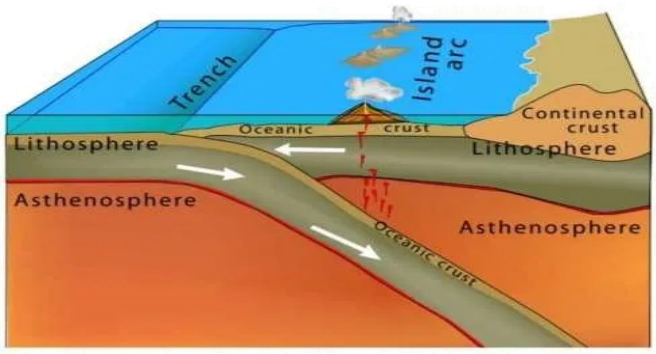
- **Destructive Edge**: The region where the oceanic plate is destroyed as it melts and assimilates into the mantle.

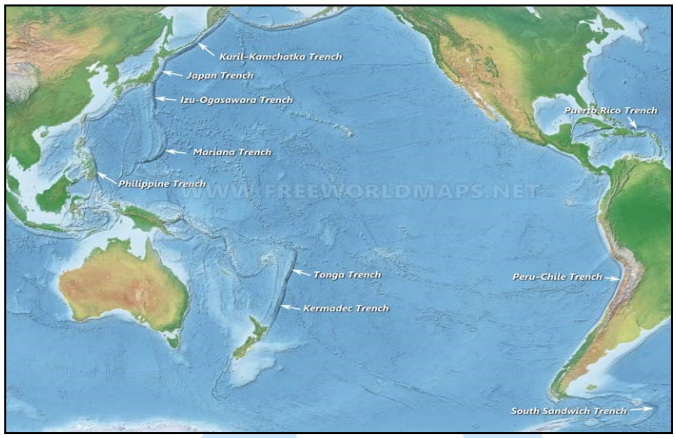
Implications:

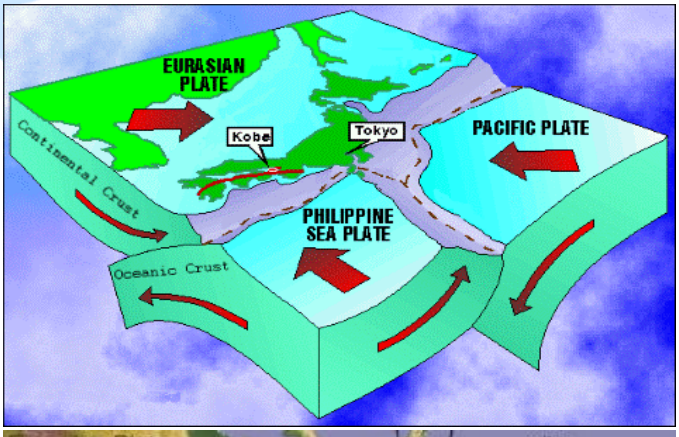
- **Volcanic Activity**: As the oceanic plate subducts, it can melt and cause magma to rise, leading to volcanic eruptions.
- **Earthquakes**: The movement of plates and the activity at the subduction zones can also lead to seismic activities.

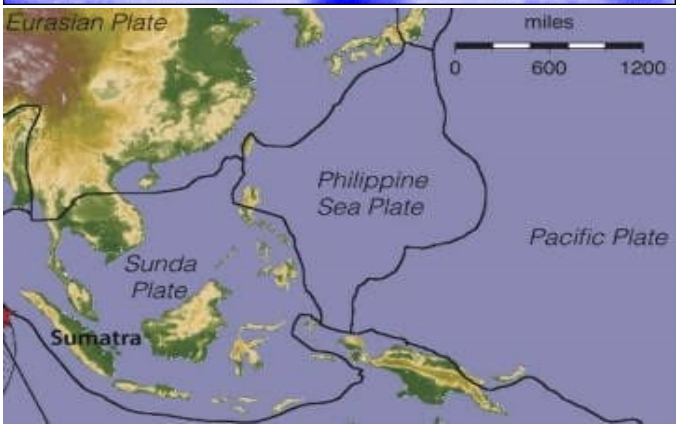
OCEANIC-OCEANIC CONVERGENCE



- When two oceanic plates meet and collide against each other, the denser of the two plates is pulled under the other and is subducted.
- It descends into the asthenosphere, or upper mantle, where it will lead to the generation of new magma.
- A denser oceanic plate subduct below a less-denser oceanic plate forming a trench along the boundary
- Normally the older plate will subduct because of its higher density
- After a certain depth, oceanic plate melts and magma chambers are produced
- Newly produced magma is lighter than the surrounding magma, and It begins to ascend by melting and fracturing its way through the overlying rock material.
- This magma comes in the form of volcanic eruption cone
- In the initial stage, these cones are below the water surface but rise above the water level after a period of time
- Constant volcanism above the subduction zone creates layers of rocks. As this process continues for millions of years, a volcanic landform is created which in some cases rises above the ocean waters.
- Such volcanic landforms all along the boundary form a **chain of volcanic islands** which are collectively called as **Island Arcs**
- By this I process, it produces island chain
- examples are: **Japan, Philippines etc.**







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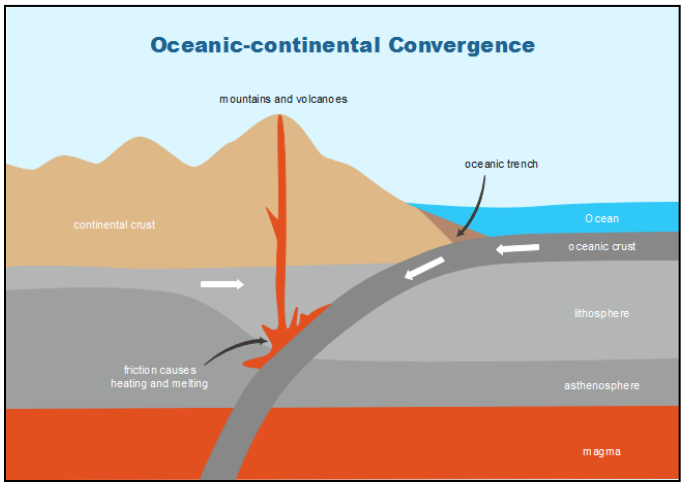
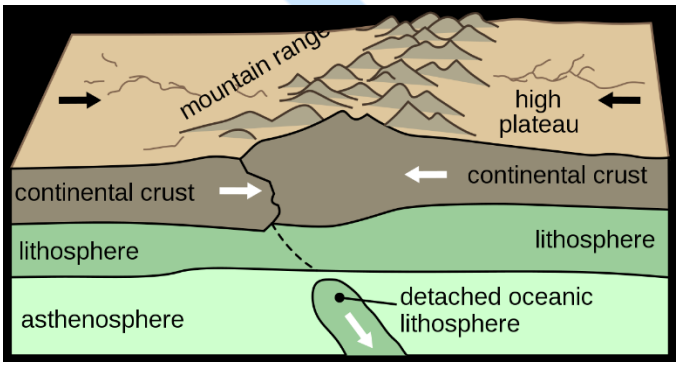
OCEANIC-CONTINENTAL CONVERGENCE

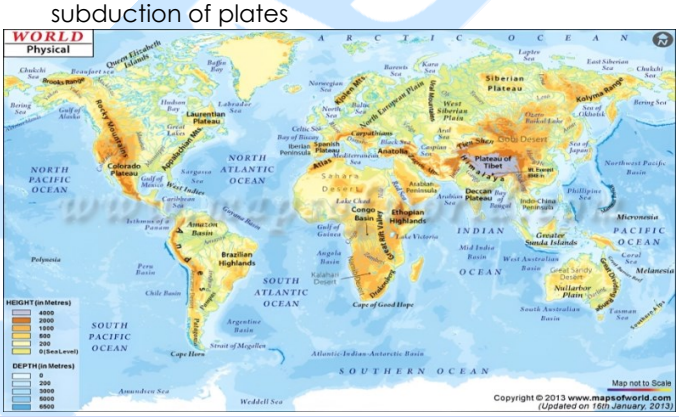


- When oceanic crust converges with continental crust, the denser oceanic plate plunges beneath the continental plate.
- Continent-Ocean Convergence is also called **Cordilleran Convergence**
- When oceanic and continental plates collide or converge, the oceanic plate (denser plate) subducts or plunges below the continental plate (less dense plate) forming a **trench** along the boundary.
- The subducting plate causes melting in the mantle above the plate. The magma rises and erupts, creating volcanoes.
- Subduction zones have a lot of intense earthquakes and volcanic eruptions.
- Such volcanic eruptions all along the boundary form a chain of volcanic mountains which are collectively called as a **continental arc**
- Examples: - the Cascade Range (parallel to the Rockies), the Western Chile range (parallel to the Andes)

CONTINENTAL-CONTINENTAL CONVERGENCE



- When the continent and continent converge, the crust at both the sides is too light to be subducted, so neither plate is subducted in this case.
- Neither plate subducts or even if one of the plates subducts, the **subduction zone will not go very deep.**
- The two plates converge, buckle up (**suture zone**), fold, and fault.
- **Fragments of crust or the sediments in continent margins are squeezed up with great compressional forces.**
- The intense compression can also cause extensive folding and faulting of rocks within the two colliding plates.
- It forms a large, continuous fold Mountains. Example- **The Himalayas, Alps, Urals, Appalachians** and **the Atlas Mountains**.
- Due to intense pressure between the colliding plates, metamorphic rocks formation is common at such boundaries.
- Volcanoes are not common at Continent-continent convergent boundaries because there is no subduction of plates



THE INDIAN PLATE MOVEMENT

- The Indian plate consists of Peninsular India and the Australian continental parts.
- The continent-continent convergence boundary is in the northern plate with the subduction zone alongside the Himalayas
- It extends in the east through Rakinyoma Mountains of Myanmar in the direction of the island arc along the Java Trench.
- To the east of Australia, the eastern margin is a spreading site lying inside the shape of an oceanic ridge in South-West Pacific.
- The Western margin follows Pakistan's **Kirthar** Mountain
- It extends alongside the Makrana coast and joins the spreading site from the Red Sea rift south-eastward alongside the Chagos Archipelago
- The boundary between the Antarctic plate and India is also marked by way of an oceanic ridge (divergent boundary) running in West-East route and merging into the spreading site, a little south of New Zealand.

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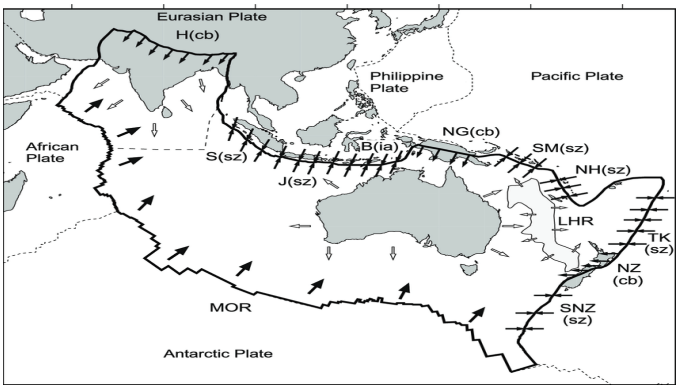
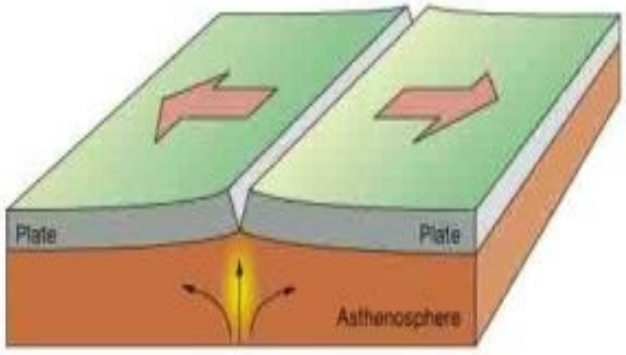
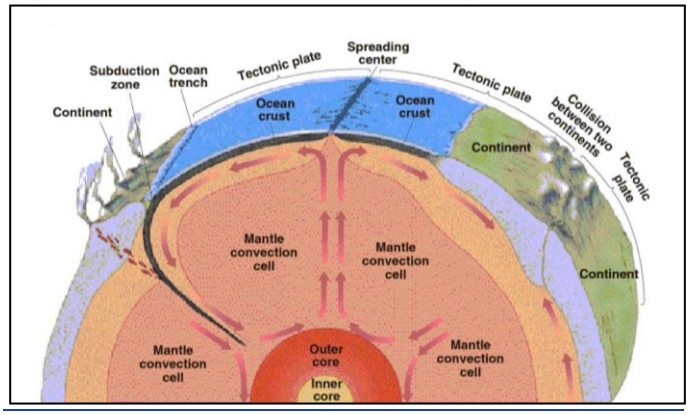


- The Tethys Sea separated India from the continent Asian until approximately 225 million years ago.
- India started her northward journey approximately two hundred million years ago
- India collided with Asia approximately 50-60 million years in the past resulted in fast uplift of the Himalayas.
- The eruption of lava and formation of the Deccan Traps.

DIVERGENT BOUNDARIES

- Divergent plate boundaries can be defined as the locations where the lithospheric plates move **away** from each other.
- Divergent plate boundaries occur above **the rising convection** currents in the asthenosphere.
- These rising currents push up the bottom of the lithospheric plate, and the magma flows laterally below it
- At a divergent boundary, magma from the asthenosphere wells up in the opening between plates.
- This upward flow of molten material produces a line of volcanic vents that spill out basaltic lava onto the ocean floor, with the plutonic rock gabbro solidifying deeper below.
- In these areas, the divergent plate boundaries are associated with submarine mountain ranges such as the mid-Atlantic ridge, volcanic activities in the form of fissure eruptions, seafloor spreading and shallow earthquakes.
- At the divergent plate boundaries, new lithospheric plates are created while the **old lithospheric** plates get destroyed somewhere else at the convergent plate boundaries.
- Divergence (divergent boundary) is responsible for the **evolution and creation of new seas and oceans** just like convergent boundaries are responsible for the formation of **fold mountains, volcanic arcs**.





DIVERGENT BOUNDARIES- OCEANIC

- When the divergent plate boundaries occur below the oceanic lithosphere, the rising convection currents from the magma lifts the lithospheric plate and produces a mid-oceanic ridge.
- The lithospheric plate is stretched due to the extensional forces and produce a deep fissure.
- When this fissure opens, the pressure on the heated magma is reduced.

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- New magma flows through this fissure, which comes out and solidifies.
- Divergent plate boundaries examples include the mid-Atlantic Ridge
- The area around the ridge is higher compared to the surrounding sea floor
- In these areas, the divergent plate boundaries are associated with submarine mountain ranges such as the mid-Atlantic ridge, volcanic activities in the form of fissure eruptions, seafloor spreading and shallow earthquakes.

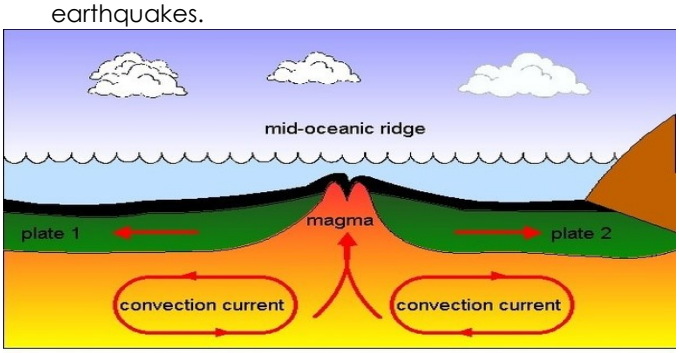
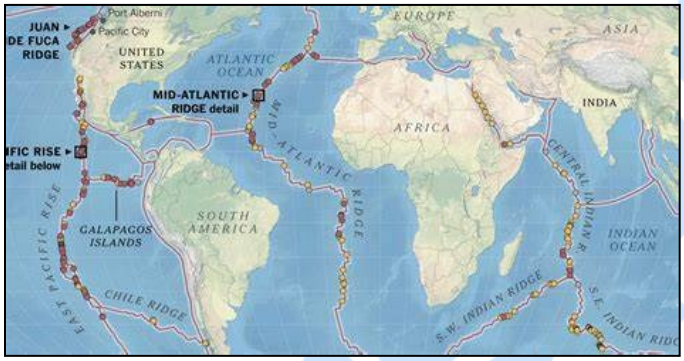
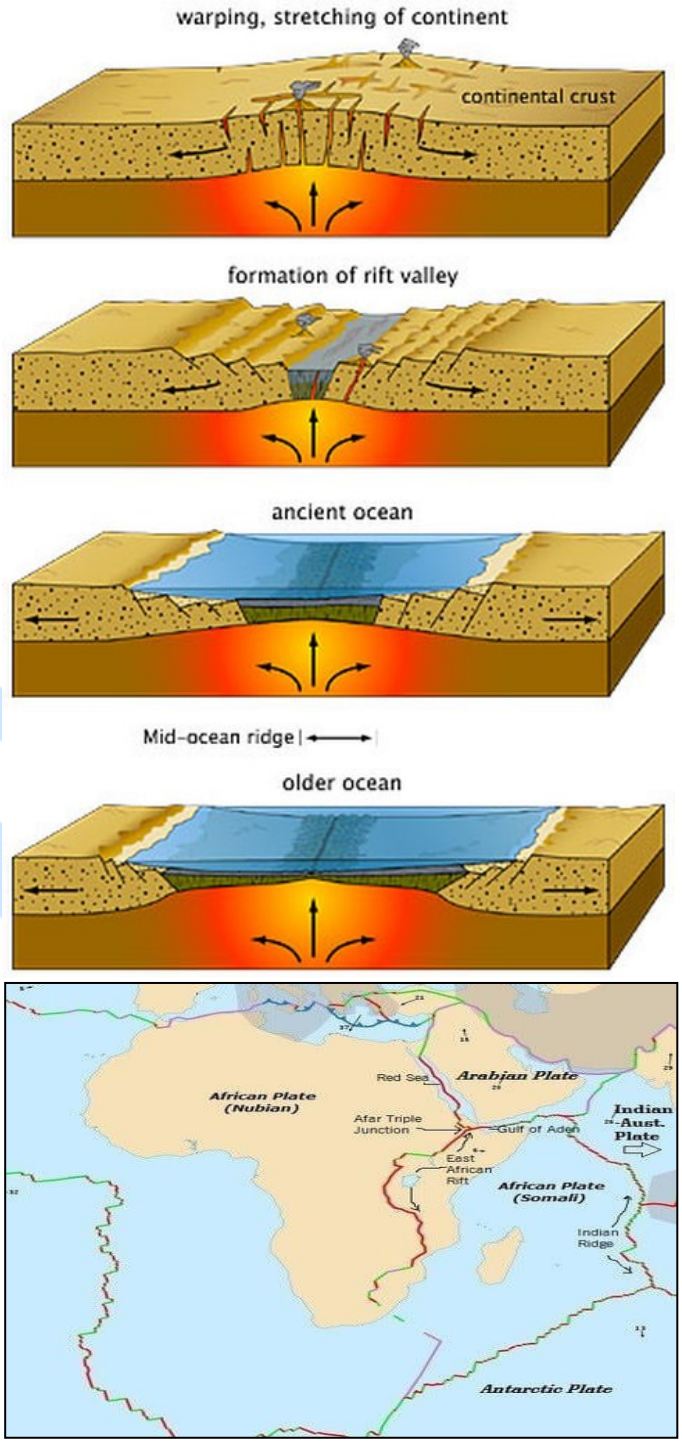


Plate 1 and plate 2 move apart. Magma rises, cools and solidifies forming new igneous rock. This is sea-floor spreading and is a constructive plate boundary.



DIVERGENT BOUNDARIES- CONTINENTAL

- When the two Continental plates are pulled apart, faults develop on both sides of the rift.
- The central block of the plate slides downwards and earthquakes occur due to this movement.
- In the early part of the rift forming process, streams and rivers flow through this sinking rift valley which can form a long linear lake.
- If the rift grows deeper, its level can fall below the sea level and the ocean water can **enter** inside it.
- This can lead to the formation of a narrow sea inside the rift.
- If this rifting process continues, new ocean basin could be formed in that place.
- This type of divergent plate boundaries includes **the East African Rift Valley**, which is in the early stage of development
- The example of the completely developed rift valley is the Red Sea.



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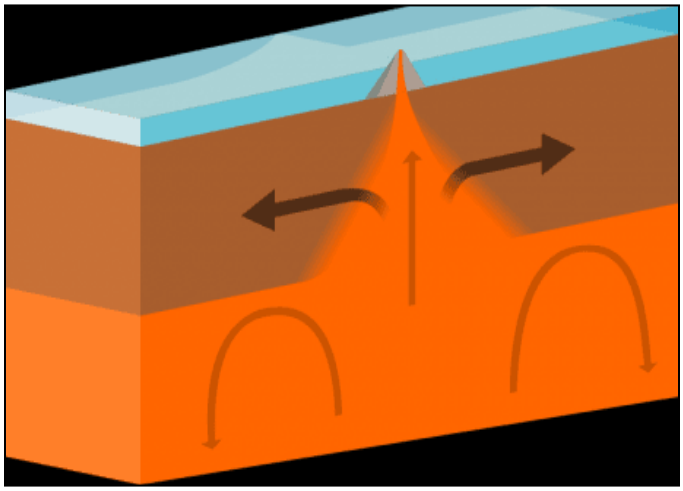
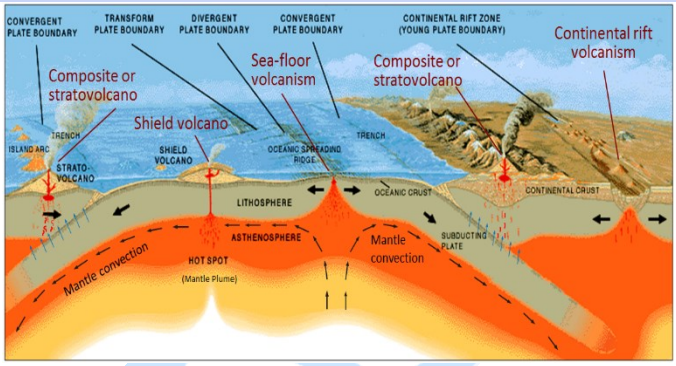


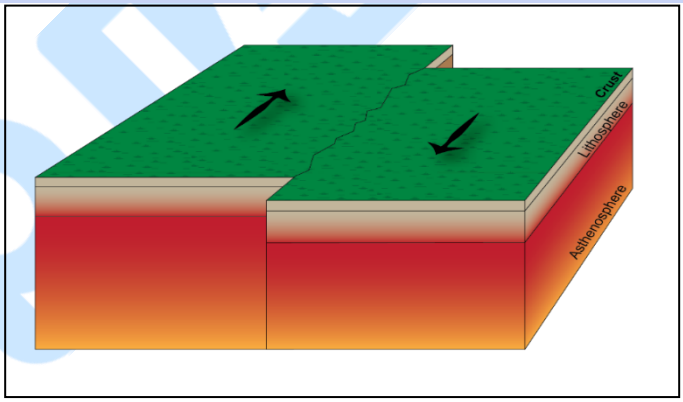
DIVERGENT BOUNDARY (SUMMARY)

- Rising Magma continuously hit the Lithospheric plates
- After millions of years, plates become weak and finally breaks up.
- Magma from beneath comes to the surface.
- Both plates diverge in both sides.
- Rising magma creates new plates at the margins of the plates. That is why it is called Constructive Plate Boundaries.
- When the divergent plate boundaries occur below the oceanic lithosphere, the rising convection currents from the magma lifts the lithospheric plate and produces a mid-oceanic ridge.
- Here, sea Floor spreading takes place, as new plate is formed and old one is destroyed.
- Example- Mid Oceanic Ridge
- LANDFORMS and Stages: - **fault zones, Rift Valley Formation, Linear Sea or Rift Lakes, Linear Sea transforms into Ocean**

FULL DIAGRAM OF PLATES



TRANSFORM BOUNDARIES



- Plates moving parallel to each other in opposite directions*
- Fault is created.
- It does not create Rift, but only large cracks
- **Examples**: - San Andreas Fault in California, Chilean Fault, New Zealand Fault
- In Mid Oceanic ridge also, we find transform boundaries because plates are moving with different speeds.

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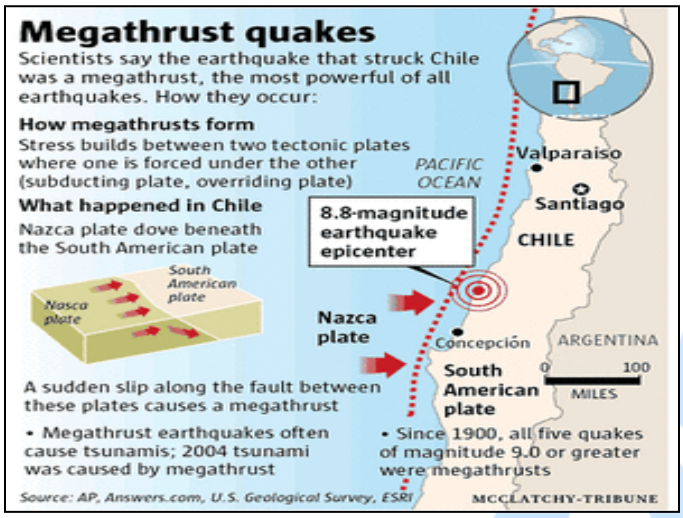
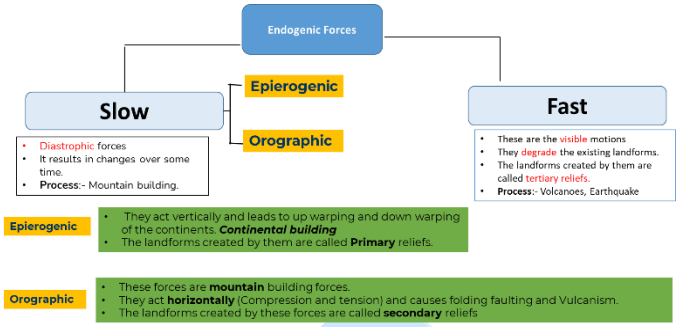
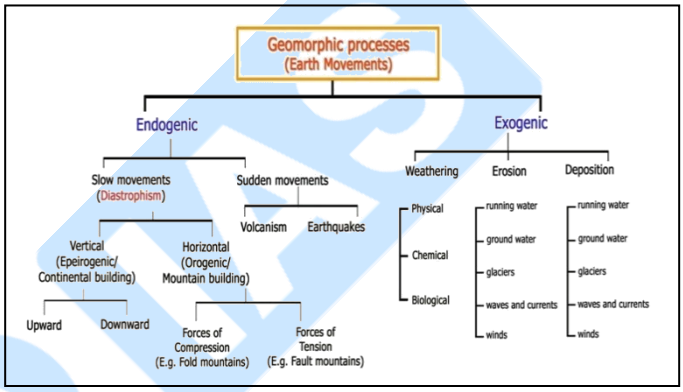


ENDOGENIC AND EXOGENIC FORCES

ENDOGENIC FORCES – INTERNAL FORCES

- Endogenic forces or endogenetic forces are the pressure that originates **inside** the earth, therefore also called internal forces
- Since they create new landforms, they are also known as the **Forces of Construction.**
- These internal forces lead to **vertical and horizontal** movements and result in ***subsidence, land upliftment, volcanism, faulting, folding, earthquakes,*** etc.
- Endogenic forces are land building forces that play a crucial role in the formation of the earth's crust.
- ***Primordial heat, radioactivity, tidal and rotational friction*** from the earth results in the creation of this energy.
- The main processes involved under this are volcanism, folding, and faulting.





EXOGENIC FORCES

- They are forces impacting the earth's surface by the elements of nature – **Air, Water, ice.**
- They are land weathering forces.
- Sun is the primary source of energy.
- **Other Sources: -** Atmosphere, Gravitation, Gradients
- The forces deriving their strength from the earth's exterior or originating in the earth's atmosphere are called exogenic forces
- Also called External forces
- They often cause wearing down in the earth's surface.
- Also called **land wearing** force.
- **Examples**: - Weathering, mass wasting, erosion, deposition etc.

EARTHQUAKE

WHAT IS EARTHQUAKE?

In very simple language, the earthquake is the *shaking of the earth*. An earthquake can be defined as a sudden *violent shaking of the ground* as a result of movements in the earth's crust. These movements result shaking of the earth in the release of energy and this releasing of energy causes this shaking and ultimately, **Earthquake**.

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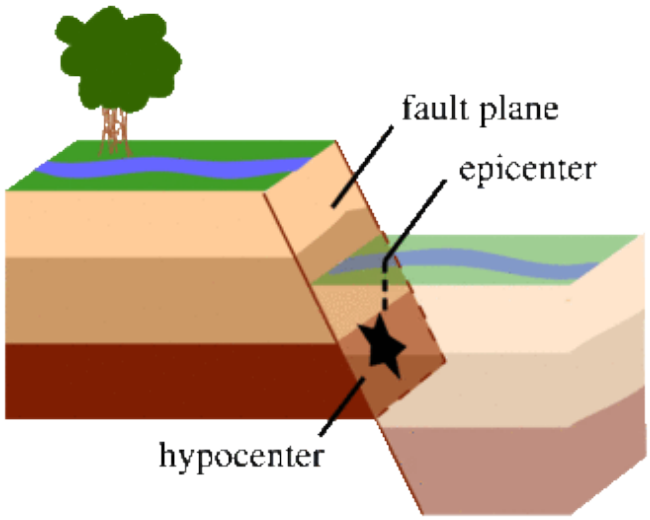
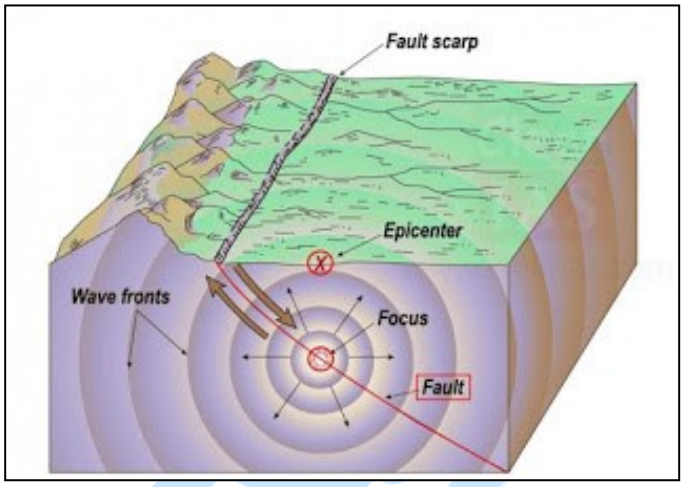


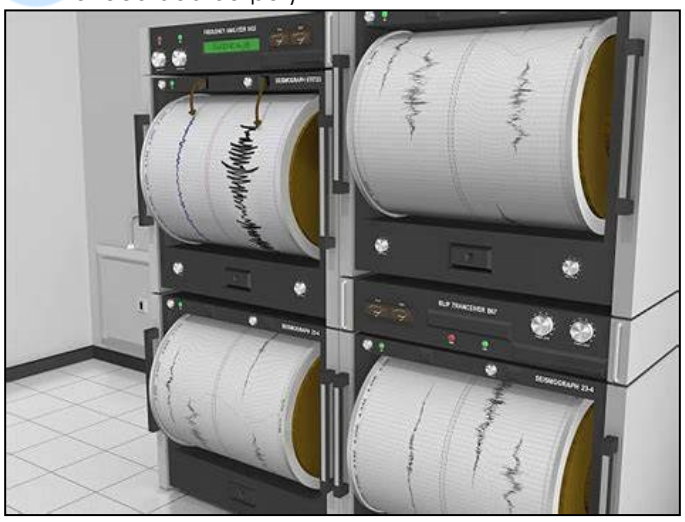
CAUSES OF EARTHQUAKE

- Earth has a layered structure inside and the outermost hard rock-solid layer is called the Lithosphere which is formed by the combination of **CRUST** and **UPPER-UPPER** Mantle**.**
- These are called **TECTONIC PLATES.** These plates are in continuous motion and they never rest. During their movement, these plates interact with each other.
- Edges of the plates are called Boundaries and that edge where these boundaries interact is called Plate Boundaries.
- Plate boundaries are not smooth, rather they are **rough** and **nonlinear**.
- When they move or slide past each other, they are locked with each other. The rest of the plate is **still moving**.
- Hence **after a point**, their lock is released and they also release a lot of energy which was earlier stored.
- The energy radiates outward from the fault in all directions in the form of **seismic waves** like ripples on a pond.
- The seismic waves **shake** the earth as they move through it, and when the waves reach the earth's surface, they shake the ground and anything on it, like our houses and us!
- The point within the earth's crust where an earthquake originates is called the **focus** or hypocenter or seismic focus.
- It generally lies within a depth of 6 km in the earth's crust.
- The point vertically above the focus on the earth's surface is called the **epicenter.**
- The **intensity** of the earthquake will be **highest** in the epicenter and decreases as one moves away.
- All-natural earthquakes take place in the lithosphere



MEASUREMENT OF EARTHQUAKE

- **Seismometers** are the instruments which are used to measure the motion of the ground, which including those of seismic waves generated by earthquakes, volcanic eruptions, and other seismic sources.
- **A Seismograph** is also another term used to mean **seismometer** though it is more applicable to the older instruments.
- The recorded graphical output from a seismometer/seismograph is called a **seismogram**. (Note: Do not confuse seismograph with seismogram. A seismograph is an instrument while seismogram is the recorded output)



There are two methods/scales to measure earthquakes

(A) Intensity-based measurement/scales

1. **MSK Scale** -It is a macro-seismic intensity scale used to evaluate the severity of ground shaking on the basis of observed effects in an area of the earthquake occurrence.
2. **Marcalii Scale:** -The scale represents the **intensity** of an earthquake by analyzing the after-effects like how

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many people felt it, how much the destruction occurred etc. The range of intensity is from 1-12.

(B) Magnitude Based Measurement/scale: -

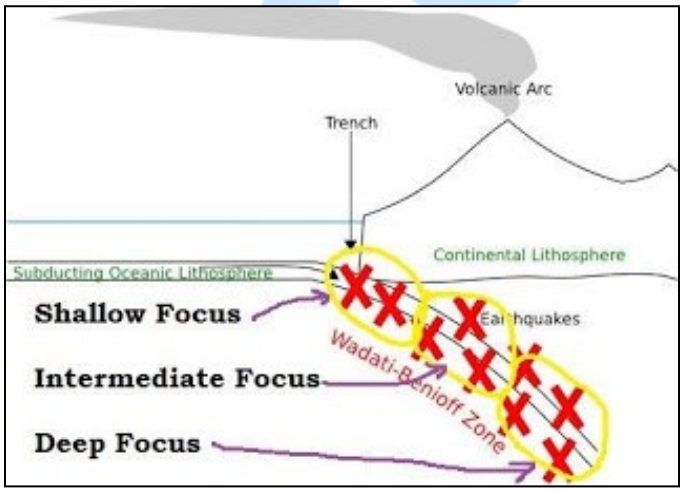
1. **Richter Scale:** - It is based on the amplitude of the the largest wave recorded on a specific type of seismometer and the distance between the earthquake and the seismometer.
2. **The Moment Magnitude Scale: -** Unfortunately, many scales, such as the Richter scale, do not provide accurate estimates for large magnitude earthquakes So, **moment magnitude the scale** is preferred. The moment magnitude scale is based on the total moment release of the earthquake. The moment is a product of the distance a fault moved and the force required to move it.

TYPES OF EARTHQUAKES BASED ON DEPTH

- **Shallow earthquakes (0–70 km):-** they are also called "**crustal earthquakes**". Most of them are originate in Lithosphere. The majority of them are of a smaller magnitude.
- **Intermediate earthquakes: -** (70–200 km deep)
- **Deep Earthquakes (300–700 km): -** In general, the term "**deep-focus earthquakes**" is applied to earthquakes deeper than 70 km. These are found in Subduction zones and this is called Benioff Zones. They are also are known as "**Intraplate Earthquakes**" The deepest earthquake ever recorded was a 4.2 earthquake in **Vanuatu** at a depth of 735.8 km in 2004.

WHAT IS WADATI- BENIOFF ZONES?

This is the zone where **deepest**, deadliest and the most number of Earthquakes are experienced. This zone is found on Subduction zones, or in Convergent Plate Boundaries.

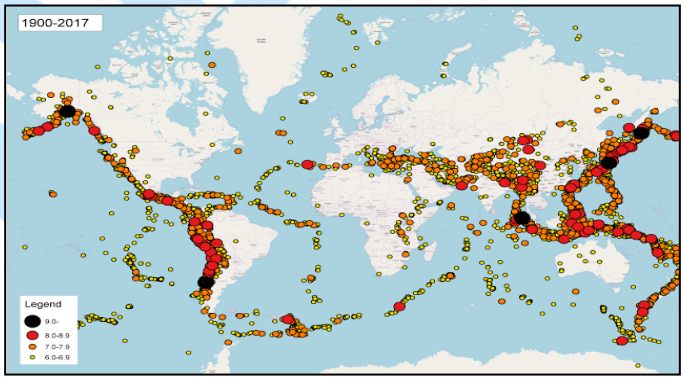


DISTRIBUTION OF EARTHQUAKES

Earthquakes are not evenly distributed on the planet. There are regions where maximum intensity earthquakes are experienced, whereas, few other regions experience low-intensity and very few Earthquakes.

MAJOR EARTHQUAKE PRONE REGIONS

1. **Circumvent Pacific Region:-** It starts from the Southern tip of Andes and ends at the Northern tip of Rockies. It further leads to the Aleutian Islands, Japan, Philippines, and New Zealand. This region experienced nearly 70% of the planets' total Earthquakes. This region is marked with many volcanic eruptions also. That is why it is also called a ***RING OF FIRE (*** as shown in Diagram)
2. **Mediterranean-Himalayan Region:-** This is the second most Earthquake-prone region that receives around 20% of Earthquakes.
3. **Other Regions:**- East African Rift Valley, Mid Atlantic Ridge and Caribbean Islands along with other Earthquake Prone Regions.



SEISMIC WAVES- WHAT IT IS AND THEIR ROLE?

- **When** energy is released from the Focus point/Hypocenter, it travels in all the directions. **Till** the time this energy is inside the earth, we don't feel any shaking When this energy is received by the surface of the earth, we feel shaking of the ground.
- This energy travels through waves.
- First, these waves travel through the interior/body of the earth and then on the surface.
- These waves are called **Seismic** waves. These seismic waves can be categorized into two parts:-

1. **Body Waves-** P-waves and S-waves
2. **Surface waves**- Love waves and Rayleigh Waves

BODY WAVES

P-Waves

- The first kind of body wave is the **P wave** or **primary wave**.

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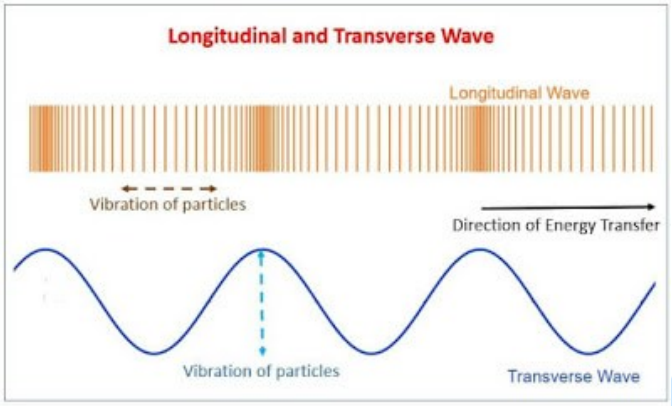
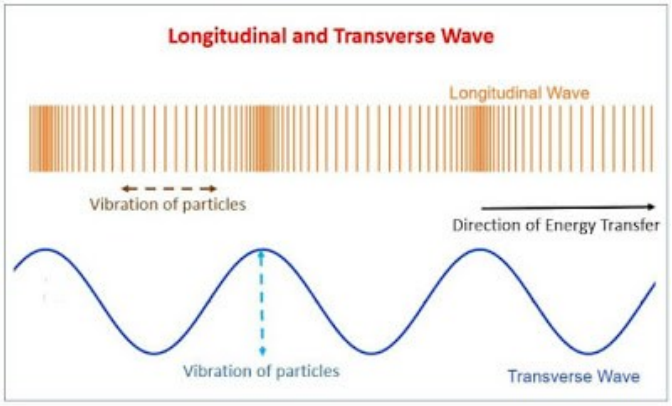
- This is the fastest wave, and they are the first to 'arrive' at a seismic station.
- The P wave can travel through all mediums -solid rock, liquid, and gases
- They travel like Sound waves
- P waves are also known as **compressional waves**
- P waves are also called Pressure waves.
- These are Longitudinal waves *because particles move in the same direction that the wave is moving in,* which is the direction of wave propagation.
- Change their direction when passes through the mediums of different density



S-waves

- These are the secondary wave, which is the second wave we feel in an earthquake.
- S wave is slower than a P wave
- These waves can travel only through Solid
- S waves move rock particles up and down, or side-to-side
- These are transverse waves or shear waves or distortional waves.
- The direction of vibrations of the particles in the medium is perpendicular to the direction of propagation of the wave.
- They create **troughs** and **crests** in the material through which they pass
- S-waves are important to know that the outer core of the earth is Liquid in nature.



SURFACE WAVES

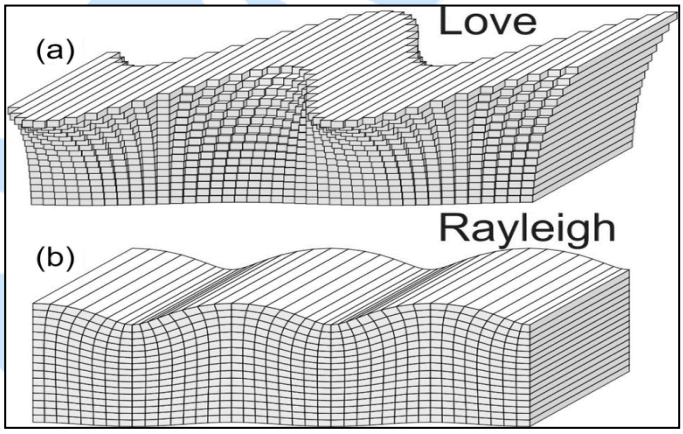
- Surface waves are of a **lower frequency** than body waves. Though they arrive after body waves, it is surface waves that are almost entirely responsible for the damage and destruction associated with earthquakes.

Love Waves

- It's the fastest surface wave and moves the ground from **side-to-side**. Love waves produce entirely **horizontal motion.**

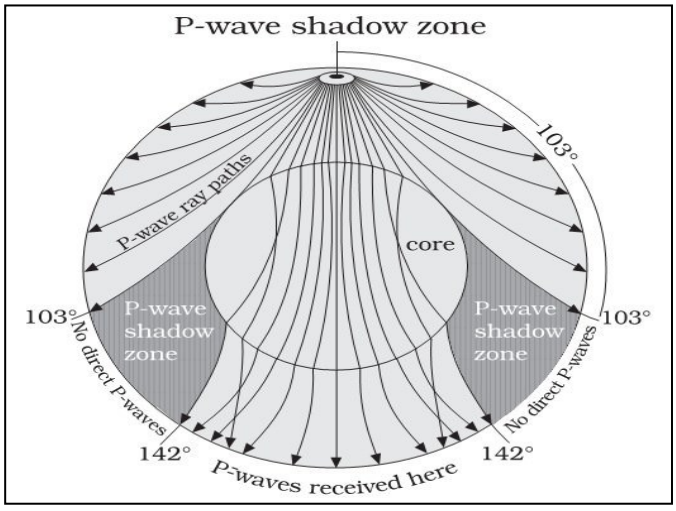
Rayleigh Waves

- These waves are like **waves in water.** A Rayleigh wave **rolls along the ground** just like a wave rolls across a lake or an ocean. It moves the ground up and down and side-to-side in the same direction that the wave is moving. Most of the **shaking** felt from an earthquake is due to the Rayleigh wave.



SHADOW ZONE

- Earthquake waves get recorded in seismo-graphs 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'***



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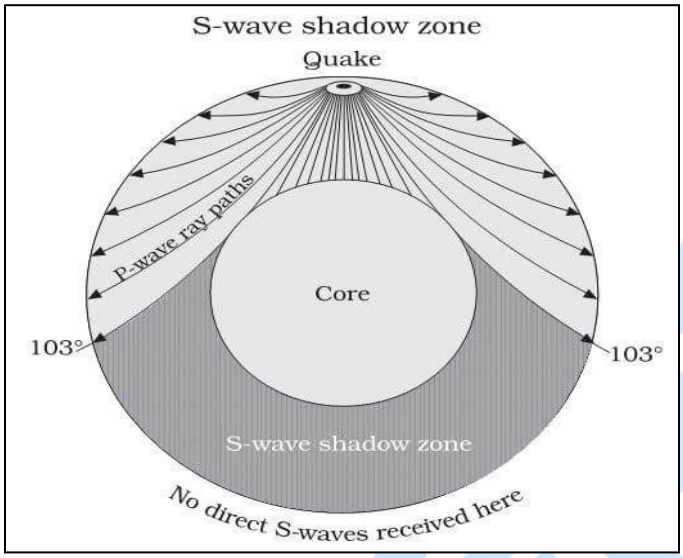
- It was observed that seismographs located at any distance within **105°** from the **epic entre**, recorded the arrival of both P and S-waves.
- The seismographs located **beyond 145°** from epic centre, record the arrival of P-waves, but not that of S-waves.
- Thus, a zone between **105° and 145° from epic-centre** 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.



PREVIOUS YEAR QUESTIONS

Q. Consider the following
1. Electromagnetic radiation
2. Geothermal energy
3. Gravitational force
4. Plate movements
5. Rotation of the earth
6. Revolution of the earth Which of the above are responsible for bringing dynamic changes on the surface of the earth? [2013]

(a) 1, 2, 3 and 4 only
(b) 1, 3, 5 and 6 only
(c) 2, 4, 5 and 6 only
(d) 1, 2, 3, 4, 5 and 6
Answer: (a)

Q. Consider the following statements:
1. In a seismograph, P waves are recorded earlier than S waves.
2. In P waves, the individual particles vibrate to and fro in the direction of wave propagation whereas in S waves, the particles vibrate up and down at right angles to the direction of wave propagation.

Which of the statements given above is/are correct? [2023]
(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2
Answer: (c)

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