PETRLOLOGY:

Petrology is science of rocks. A petrologist studies rocks in all their aspects viz., mineral composition, texture, structure, origin, occurrence, alteration and relationship with other rocks.

About 98 per cent of the total crust of the earth is composed of eight elements - oxygen, silicon, aluminium, iron, calcium, sodium, potassium and magnesium.

MINERALS

Define Mineral:

- Rocks are combinations of homogenous substances called Minerals
- a mineral is a naturally occurring organic and inorganic substance, having an orderly atomic structure and a definite chemical composition and physical properties.
- A mineral is composed of two or more elements.
- But, sometimes single element minerals like sulphur, copper, silver, gold, graphite etc. are found
- The mineral resources provide the country with the necessary base for industrial development.
- Minerals such as coal, petroleum and natural gas are organic substances found in solid, liquid and gaseous forms respectively.
- There are at least 2,000 minerals that have been named and identified in the earth crust; but almost all the commonly occurring ones are related to six major mineral groups that are known as major rock forming minerals.

Source :

- The basic source of all minerals is the hot magma in the interior of the earth.
- When magma cools, crystals of minerals appear and a systematic series of minerals are formed in sequence to solidify so as to form rocks.

In Igenous and Metamorphic Rocks - Minerals may occur in the cracks, crevices, faults or joints. The smaller occurrences are called " veins" and the larger are called " lobes".
Ex Metallic Minerals like tin, copper, zinc and lead are obtained from veins and lobes.

In Sedimentary rocks a number of minerals occur in beds or layers. They have been formed as a result of deposition, accumulation and concentration in horizontal strata. Ex coal

Sedimentary Minerals : Gypsum, Potash salt and sodium salt : formed as a result of evaporation in arid regions

Another mode of formation involves the decomposition of surface rocks and removal of soluble constituents , leaving a residual mass of weathered material containing ores. ex Bauxite

Certain minerals may occur as alluvial deposits in sands of valley floors and the base of hills. These deposits are called " placer deposits".
Ex Gold, Silver , Platinum , tin etc

The ocean water contain vast quantities of minerals ex common salt, magnesium and bromine are largely derived from ocean waters. The ocean beds rich in manganese nodules

SOME MAJOR MINERALS AND THEIR CHARACTERISTICS:

- **Feldspar:** half of the earth's crust is composed of feldspar; Silicon and oxygen are common elements in all types of feldspar; **used in ceramic and glass making**.
- **Quartz:** It is one of the most important components of sand and granite. It consists of silica. It is a hard mineral virtually insoluble in water. **Glass making , Paint , Clocks electronic instruments** It is white or colourless and used in radio and radar. It is one of the most important components of granite
- **Pyroxene**: Pyroxene consists of calcium, aluminum, magnesium, iron and silica. Pyroxene forms 10 per cent of the earth's crust.; It is in green or black colour **;commonly found in meteorites**.
- **Amphibole:** Aluminium, calcium, silica, iron, magnesium are the major elements of amphiboles. They form 7 percent of the earth's crust. Amphiboles is used in **Asbestos industry.** Hornblende is another form of amphiboles
- **Mica:** It comprises of potassium, aluminium, magnesium, iron, silica, etc. It forms 4 per cent of the earth's crust. commonly found in igneous and metamorphic rocks; **used in electrical instruments.**
- **Olivine**: Magnesium, iron and silica are major elements of olivine. It is used in **jewellery**. It is usually a greenish crystal, often found in basaltic rocks.

TYPE OF MINERALS

Rocks containing minerals in concentrated form are called Ores .
Metallic Minerals These minerals contain metal content and can be sub-divided into three types:
(i) Precious metals : gold, silver, platinum etc.
(ii) Ferrous metals : iron and other metals often mixed with iron to form various kinds of steel.
Ex iron ore, manganese, cobalt and nickel.
(iii) Non-ferrous metals : include metals like copper, lead, zinc, bauxite, tin, aluminium etc.

Non-Metallic Minerals These minerals do not contain metal content. Sulphur, phosphates and nitrates are examples of non-metallic minerals. Cement is a mixture of non-metallic minerals.

Metallic minerals	Non-metallic minerals
(*a*) Minerals from which metals are extracted are called metallic minerals.	(*a*) Minerals consisting of non-metals are called non-metallic minerals.
(*b*) These minerals are malleable and ductile.	(*b*) These minerals are neither malleable nor ductile.
(*c*) These minerals are associated with igneous and metamorphic rocks.	(*c*) Non-metallic minerals are associated with sedimentary rocks.
(*d*) They are usually hard and have shine or luster of their own.	(*d*) They are not so hard and have no shine or luster of their own.
(*e*) For example, iron, copper, bauxite, tin, manganese etc.	(*e*) For example, coal, salt, clay etc. (*any three*)

- Metallic Minerals Good conductors of electricity as well as Heat High Malleability, ductility and lustre and high density.
- Non Metallic Minerals : Good Insulators of electricity and heat ; Lack in Malleability, ductility and lustre and breakdown easily .
- Conductors allow electric current to flow through them, while insulators do not allow the charge or electric current to flow through them and hinder its flow.
- malleability- the property of metal by which it can be beaten into sheets.
- Ductility- the property of metal by which it can be drawn into wires.
- Sonorous- the property of metal by which it produce sound when beaten by a hammer.
- Lustrous- the property of metal by whic it appears shiny.

CONSERVATION OF MINERALS

Minerals are a non-renewable resource. It takes thousands of years for the formation and concentration of minerals. The rate of formation is much smaller than the rate at which the humans consume these minerals. It is necessary to reduce wastage in the process of mining. Recycling of metals is another way in which the mineral resources can be conserved.

Global Mineral Producing Countries, India Rank 4, After China, USA, Russia.

Why India has more Mineral :

- rich variety of mineral resources due to its varied geological structure.
- Bulk of the valuable minerals are products of pre-palaezoic age
- and are mainly associated with metamorphic and igneous rocks of the peninsular India
- Most of the metallic minerals in India occur in the peninsular plateau region in the old crystalline rocks.
- The vast alluvial plain tract of north India is devoid of minerals of economic use

ROCKS

- Science of Rocks- Petrology
- Rocks are combinations of homogenous substances called Minerals
- Rocks are aggregates of one or more minerals that do not have definite chemical composition
- The earth's crust is composed of rocks.
- A rock is an aggregate of one or more minerals.
- Rock may be hard or soft and in varied colours.
- For example, granite is hard, soapstone is soft. Gabbro is black and quartzite can be milky white.
- Rocks do not have definite composition of mineral constituents.
- Feldspar and quartz are the most common minerals found in rocks.

Rocks which are grouped under three families on the basis of their mode of formation.
They are:

- Igneous Rocks — solidified from magma and lava;
- Sedimentary Rocks — the result of deposition of fragments of rocks by exogenous processes;
- Metamorphic Rocks — formed out of existing rocks undergoing recrystallisation.

WORLD DISTRIBUTION		
Igneous Rocks	**Sedimentary Rocks**	**Metamorphic Rocks**
• **Oceanic Crust:** Basalt dominates oceanic crust formed by lava cooling at mid-ocean ridges. • **Subduction Zones:** Andesite & rhyolite found at volcanic arcs. • **Continental Rifts:** Basalt & phonolite formed in continental rift zones. • **Hotspots:** Basalt and pumice found at hotspots like Hawaiian Islands and Yellowstone.	• **Coastal Areas:** Sandstones, shales, and limestones found in coastal regions of the world. • **River Basins:** e.g., Ganga and Mississippi) contribute to sedimentary rocks formation. • **Continental Shelves:** Sediment accumulates, forming sandstones and mudstones. • **Deep Ocean Basins:** Fine-grained sediments create mudstones and siltstones.	• Mountain Belts like the Alps & Himalayas. • **Subduction Zones:** Blueschist and eclogite form under high-pressure, low-temperature conditions.

DISTRIBUTION OF ROCKS IN INDIA		
Igneous Rocks	**Sedimentary Rocks**	**Metamorphic Rocks**
• **Deccan Traps:** Massive volcanic formations covering Maharashtra, Gujarat, Madhya Pradesh, and neighbouring states, formed 66 million years ago. • **Himalayan Region:** Consists of granite and basalt due to active mountain-building.	• **Gondwana Basins:** Sandstones, shales, and coal deposits in Damodar Valley, Son Valley, and Satpura- Godavari Basin. • **Coastal Plains:** Rocks like sandstones, clays, and alluvial deposits formed by rivers and coastal processes. • **Island Territories:** Sedimentary rocks, coral reefs, and volcanic formations. e.g.: Andaman & Nicobar Islands, Lakshadweep.	• **Aravalli Range:** Located in NW India, comprises Precambrian gneisses, schists, and quartzites. • **Himalayan Region:** Extensive gneiss and schist formed under intense pressure and temp.

IGNEOUS ROCKS OR PRIMARY ROCKS

- Word derive from latin word , means fire
- Formed due to Solidification of molten magma or lava
- Examples: Granite, gabbro, pegmatite, basalt, volcanic breccia and tuff.
- Valuable Minerals like Iron, Cobalt, Nickel are found in them.
- If Magma is solidified on the surface of the Earth , it result in extrusive rocks like Basalt . Basalt rock found in Ocean Basin
- If magma soldified inside the Earth , it result in Intrusive rocks like Granite . Granite rock ,very common rock of continent
- If molten material is cooled slowly at great depths (intrusive igneous rocks), mineral grains may be very large (Granite).
- If lava cools Slowly result in large crystal (Granite)
- If lava cools fast, it result in small crystal (Basalt)
- Sudden cooling at the surface (extrusive igneous rocks) results in small grains (Basalt).
- Intermediate conditions of cooling would result in intermediate sizes of grains.

FEATURES OF IGNEOUS ROCKS

- They are hard, granular and crystalline.
- Do not contain fossils. (azoic construct) No Life
- Unstratified (no layers)

- Do not allow water to percolate through them.
- Less affected by chemical weathering.
- No layers like sedimentary rocks.

CLASSIFICATION BASED ON LOCATION OF MAGMA SOLIDIFICATION

1. Intrusive Igneous Rocks

It is formed by the solidification of magma below the Earth's surface.
Examples

- Granite: batholith generally; Felsic.
- Gabbro: Mafic igneous rocks equivalent to extrusive basalt.
- Pegmatite & Diorite (intermediate)

2. **Extrusive Igneous Rocks**

If the magma reaches the surface and emerges as lava, it forms extrusive igneous rock.
Examples:

- Basalt (Basic rock , Darker; Dense; mafic) , Andesite, Rhyolite (felsic content more)

CLASSIFICATION BASED ON CHEMICAL COMPOSITION

- Those with a high proportion of silica are known as acidic rocks
- Those with a high proportion of basic oxides are denser and darker in appearance are known as basic rocks.
- Felsic Rocks and Mafic Rocks
- Felsic rocks are rich in silicon, oxygen, aluminium, sodium, and potassium
- Mafic rocks are rich in magnesium and iron
- If the rock is highly dominated by Magnesium and Iron, it is called Ultramafic

Economic Minerals associated with Igneous rocks:

Iron, Nickel, Copper, Lead Zinc Mg, Silver, Diamond, Gold ,Platinum, Chromite

- Examples of igneous rocks
  - Granite
  - Gabbro
  - Pegmatite and rhyolite
  - Basalt
  - Volcanic
  - Breccia
  - Tuff

SEDIMENTARY ROCKS OR SECONDARY ROCKS

Decomposition of Sediments --> Compaction of sediments --> Diffusion and lithfication of rocks --> Sedimentary rocks

- Word derive from Latin word" sedimentum ' means settle down
- formed by weathering of rocks, decomposition, Compaction of sediments. The sediments are deposited layer by layer.
- These deposits through compaction turn into rocks. This process is called lithification.
- In several sedimentary rocks, the layers of deposits maintain their characteristics even after lithification.

FEATURES OF SEDIMENTARY ROCKS

- Consist of layers and contain fossils
- So stratified ie having layers
- Can be Fossiliferous
- These rocks are found over the largest surface areas of the globe.
- They are porous and permable
- Coal is sedimentary rock
- Sandstone , limestone, shale, gypsum, coal

CLASSIFICATION OF SEDIMENTARY ROCKS

- Depending upon the mode of formation, sedimentary rocks are categorized into three groups:

  - Mechanically formed - Eg: Sandstone, conglomerate, limestone, shale, loess, etc.
  - Chemically formed - Eg: dolomite, rock salt, chert, halite, and potash
  - Organically formed- Eg: Geyserite, chalk, limestone, coal, etc.

Economic Minerals associated with Sedimentary rocks:

- Rock Salt, Gypsum(Hydrated Calcium Sulphate), Nitre(Saltptere or Nitrate of potash)
- **Pyrite or** iron sulphide, Hematite; it occurs both in sedimentary and Metamorphic rock, it gives its red colour to rocks and soils, it contain about 70% iron
- Coal-as a source of power, industrial fuel occurs in river basin of the Damodar, Mahanadi, Godavari in Gondwana sedimentary deposits.

- Petroleum formed by the tiny marine organism also occurs in the mud of sedimentary rocks. chief areas: 1. Gujrat, 2 Assam,3 Andhra pradesh-Kirshna godavari basin 4 Tamilnadu-cauvery basin5 Odhisaa, Maharastra,Arunachal, Mp,Wb,Jhkd.
- Indo gangetic plains is of sedimentary accumulation
- red fort of Delhi Agra are made of red variety of sandstones. Vidhyan highland-sandstones, shales, limestones.

Metamorphic Rocks

- These rocks form under the action of volume, pressure, and temperature (PVT) changes.
- Metamorphism is a process by which already consolidated rocks undergo recrystallisation and reorganisation of materials within original rocks.

FEATURES OF METAMORPHIC ROCKS

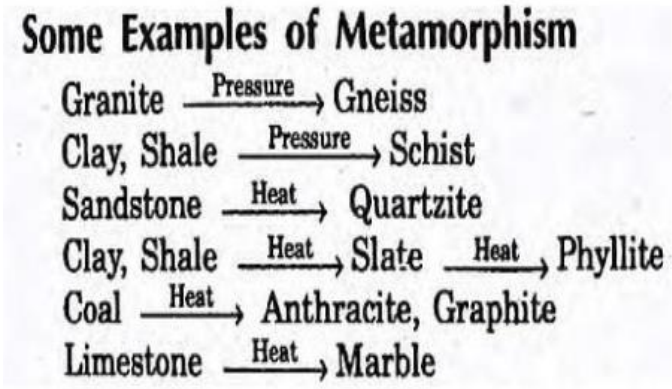
- Formed due to pressure and temperature.
- Very smooth in texture & consists of layers sometimes.
- Exhibit a wide range of colours.
- Rarely contain fossils

TYPES

- Temperature based metamorphisms is called Thermal metamorphisms
- Pressure based metamorphism is called Dynamic metamorphism
- The materials of rocks chemically alter and recrystallise due to thermal metamorphism.
- There are two types of thermal metamorphism — contact metamorphism and regional metamorphism
- Contact metamorphism: Rocks come in contact with hot intruding magma and lava and the rock materials recrystallise under high temperatures
- Regional metamorphism: Rocks undergo recrystallisation due to deformation caused by tectonic shearing together with high temperature or pressure or both.
- Metamorphic rocks are classified into two major groups — foliated rocks and nonfoliated rocks.
- In the process of metamorphism in some rocks grains or minerals get arranged in layers or lines. Such an arrangement of minerals or grains in metamorphic rocks is called foliation or lineation
- Foliated metamorphic rocks: such as gneiss, phyllite, schist and slate
- Sometimes minerals or materials of different groups are arranged into alternating thin to thick layers, appearing in light and dark shades. Such a structure in metamorphic rocks is called banding. Rocks displaying banding are called banded rocks
- Non-foliated metamorphic rocks: such as marble and quartzite which do not have a layered or banded appearance

Example

- Quartzite is a coarse-grained metamorphic rock derived from sandstone.
- Marble is a metamorphic rock that comes from metamorphosed limestone or dolomite.
- Slate is a fined grained metamorphic rock.
- Phyllite is a fined grained metamorphic rock.
- Schist is a coarse grained metamorphic rock
- Gneiss is a medium to coarse grained metamorphic rock.



Basalt change to Hornblende

DIFFERENCE BETWEEN :

SEDIMENTARY AND IGNEOUS ROCKS

S.no	Sedimentary rocks	Igneous rocks
1.	Made up of sediments.	Made up of solidified lava.
2.	Loose sediments get sedimented into rocks.	Liquid lava gets solidified by gradual cooling.
3.	Form in layers.	They are compact.
4.	Contains fossils.	Do not have fossils.
5.	Are organic and inorganic in nature.	They are extrusive or intrusive.
6.	Permeable and allow water to seep.	In permeable and do not allow water to seep.
7.	They are known as secondary rocks, these are of two types: Intrusive- granite, Diorite; Extrusive-basalt.	They are known as primary rocks e.g. organic rock-coal, limestone Inorganic- sandstone, shale.

IGNEOUS AND METAMORPHIC ROCKS

S.no	Igneous rocks	Metamorphie rocks
1.	Magma cools and solidifies.	Igneous and sedimentary rocks and are changed into metamorphie rock due to heat and temperature.
2.	Igneous rocks are normally crystalline and are of two types- Intrusive and Extrusive.	Metamorphism can be of two types contact thermal metamorphism and regional metamorphism.
3.	Hard, Impermeable in nature.	They are also hard but have formed due to change in igneous and sedimentary rocks for e.g. Limestone changes into marble, sandstone into quartzite and coal into graphite.
4.	In igneous rocks no bands are seen.	In metamorphie rocks banding is a normal.
5.	In the intensive igneous rocks the cooling and solidification decides the size of the particles.	The arrangement of the minerals of granules is called lineation.

Consider the Statements (T/ False)

1. Rocks do not have definite composition of mineral constituents .

2. Rock comprises minerals

3. Rocks do not possess definite shape and are found in different colours.

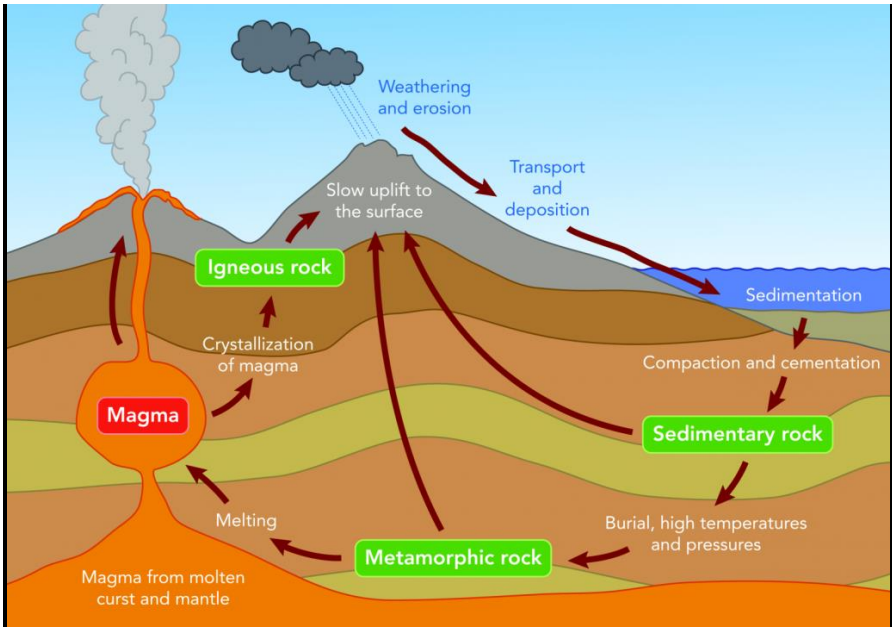
4 . A Mineral does not comprise rocks

5. Minerals are said to have a definite shape and the colour.
6. granite is It mostly consists of three minerals namely quartz, mica and feldspar.
7. These mined rocks are called as ores, and the residue of these rocks after mineral has been extracted from it is called as tailing.
8. Coal, Petroleum, Natural gas are organic Substances in Solid , liquid and gas forms respectively.

ROCK CYCLE :

- **it is multidirectional and continuous process of transformation of rock from one to another is known as rock cycle**
- the geomorphic process help in making rock cycle continuous .
- even plate tectonics movement also help in this .
- any given rock can go through any part of the cycle any number of times .

Ex : The Crustal rocks (igneous, metamorphic and sedimentary) once formed may be carried down into the mantle (interior of the earth) through subduction processes (plate convergence) and the same melt down due to increase in temperature in the interior and turn into molten magma, the original source for igneous rocks.



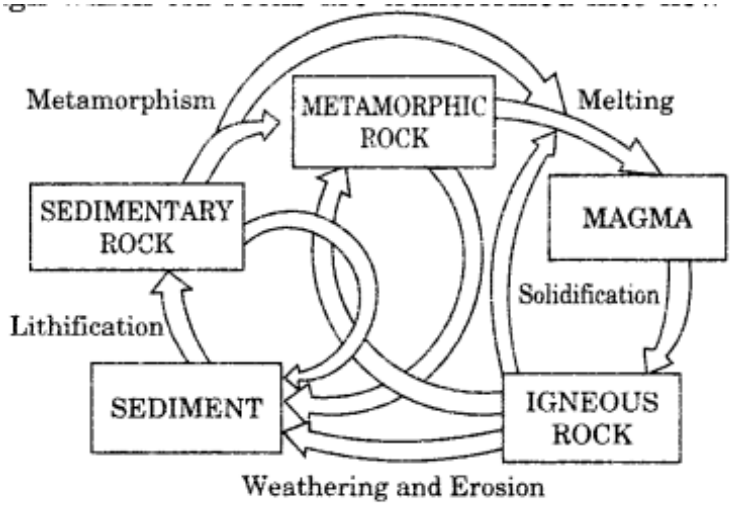
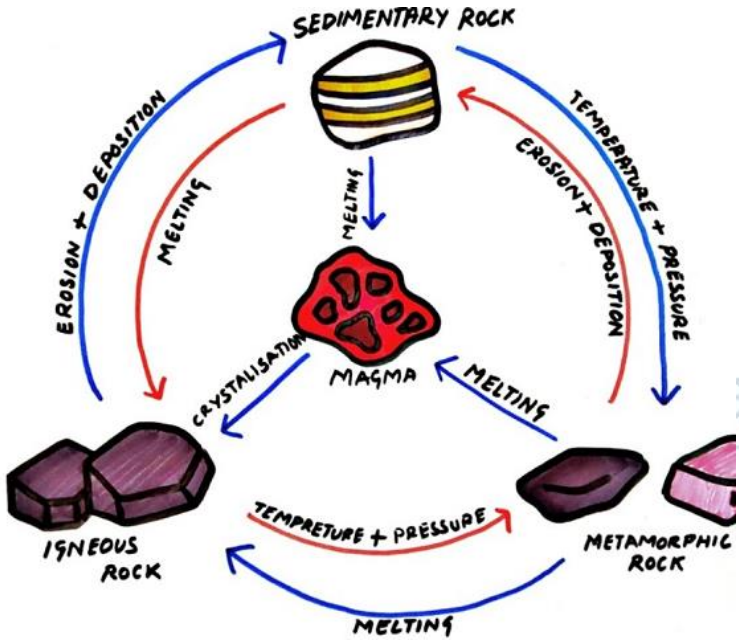


Fig: Rock Cycle



IMPORTANCE OF THE ROCK CYCLE

- Soil Production: The breakdown of rocks contributes to soil formation, which is essential for agriculture and supports life on Earth.
- Mineral Resources: The rock cycle plays a vital role in producing essential minerals necessary for human health (such as sodium, iron, potassium, calcium) as well as rare minerals used in technology.
- Precious Stones: Valuable resources like gold, diamonds, rubies are also products of geological processes involved in the rock cycle; their rarity makes them significant both economically and culturally
- Construction Materials: Many construction materials such as limestone, marble, granite, and iron ore are products of the rock cycle; these materials have been used throughout history for building civilizations.
- Energy Sources: Knowledge of the rock cycle aids in locating fossil fuels and other energy sources found within specific types of sedimentary rock formations.

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EARTHQUAKES

Seismology :

- it is the science of Earthquakes and related phenomena.
- The word "Seismology" is derived from the Greek word "Seismos" meaning earthquake and "Logos" meaning science.

Paleoseismology :

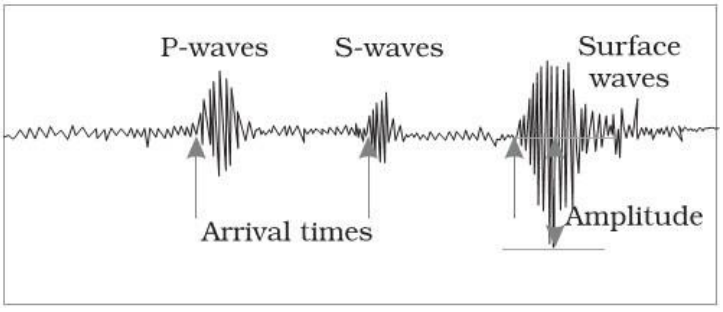
- The study of ancient (prehistoric) earthquakes

Seismicity:

- refers to occurrence , frequency and geographic and historical distribution distribution of earthquakes
- Earthquakes are generally associated with the weaker and isostatically disturbed areas of the globe

Define :

- An earthquake is the shaking and trembling of the earth triggered by the sudden release of energy along fault lines in the form of seismic waves in all directions .
- A fault is a sharp break in the crustal rocks.
- An Earthquake caused due to sudden fracture and movement of rocks along fault. (readjustment of stress along the fault zone).
- Earthquakes is Seismic Release of Stress along a fault Zone in the form of Seismic waves
- Seismic waves: are energy waves, which travel through the earth interior, due to an earthquake, are called seismic waves.
- it is most destructive catastrophic event mainly generated by internal or endogenic geomorphic process
- Seismograph : Seismic waves recorded at Seismograph



Amplitude

The maximum height of a wave crest or depth of a trough on a seismogram, used to estimate the strength of the earthquake.

Two Ways to measure different aspects of an earthquake:

- **Magnitude** : measure of the size of the earthquake (Charles Richter Scale)
- **Intensity:** measure of the shaking and damage caused by the earthquake
- Intensity scale examples - Rossi Forel Scale , Mercalli Scale , MSK-64

Key Fact :

- **Rossi–Forel scale** was one of the first seismic scales to represent earthquake intensities , used till 1902 after that Mercalli Intensity scale used widely.
- The Mercalli scale is linear and the Richter scale is logarithmic
- Mercalli Scale based on Observation; Richter scale based on Seismograph
- Mercalli Scale used Roman numbers (I to XII) ; Richter Scale (1 to 10)
- The **Medvedev–Sponheuer–Karnik scale,** also known as the **MSK** or MSK-64, is a macroseismic intensity scale used to evaluate the severity of ground shaking on the basis of observed effects in an area of the earthquake occurrence

Earthquakes are classified as

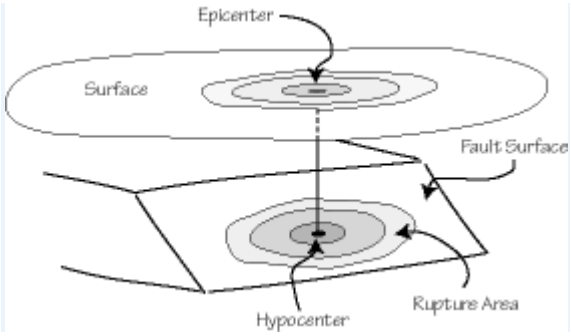
Magnitude :

- Slight (M<5.0), Moderate (5.0<M<6.9) and Great (M>7.0) depending upon the magnitude on Richter"s scale.
- An earthquake having a magnitude, M<2.0 is termed as microearthquake

Note : National Centre for Seismology (NCS) , New Delhi, is the nodal agency of the Centre under Earth sciences ministry for monitoring of earthquake activity in the country.

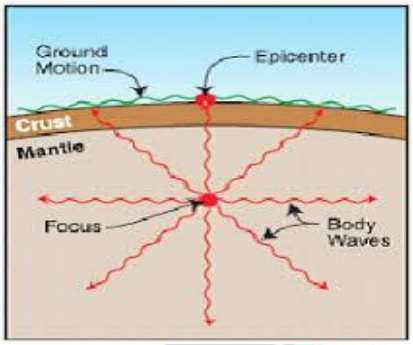
KEYWORDS :

- All natural earthquakes arise within the lithosphere, i.e., up to a depth of 200 km from the earth's surface.



Rupture Zone

- The area inside the Earth, where two blocks of rock mass slip and give rise to occurrence of an earthquake. For very small earthquakes, this zone could be very small, but in the case of a great earthquake, the rupture zone may extend to several hundred kilometers in length and tens of kilometers in width.



Hypocentre/ Focus:

- **Location** where the earthquakes starts.
- **Position on Earth:** Below Earth Surface
- **Associated waves** : Body waves
- **Dimensionality:** Used as a reference to measure 3 dimensional spread of seismic waves.

Epicentre:

- **Location** right above the hypocentre or focus .
- **Position on Earth:** On the Earth Surface
- This point is expressed by its geographical coordinates in terms of latitude and longitude.
- **Associated Waves** : Body waves and Surface Waves
- **Dimensionality**: Used as a reference to measure 2 dimensional spread of seismic waves.

Focal depth

- is the vertical distance between the Hypocentre (Focus) and Epicentre.

THEORY OF EARTHQUAKE

(Old Theory) Elastic Rebound Theory: REID

- process of gradual build-up of strain and stress punctuated by occasional sudden earthquake failure is referred to as the elastic-rebound theory.

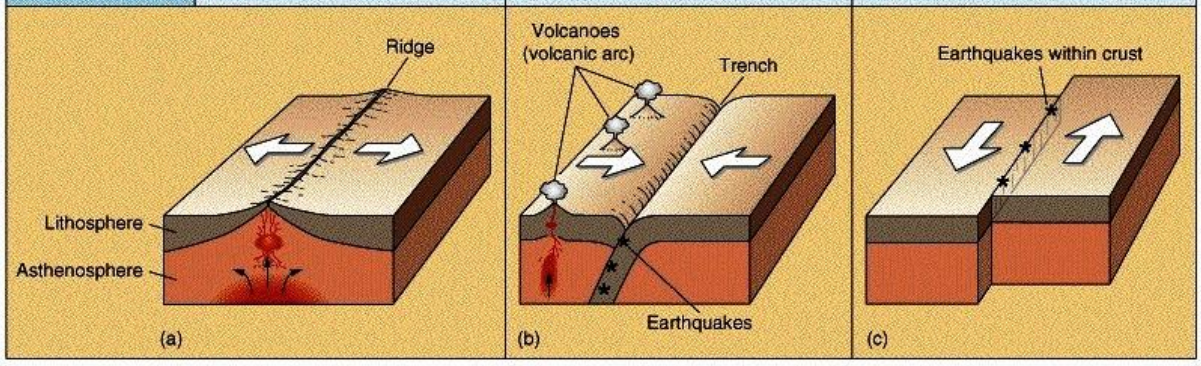
- After the great 1906 San Francisco earthquake, geophysicist Harry Fielding Reid examined the displacement of the ground surface along the San Andreas Fault in the 50 years before the earthquake.---
- He concluded that the quake must have been the result of the elastic rebound of the strain energy stored in the rocks on either side of the fault
- After the rupture event, stress buildup resumes until the next earthquake occurs. This is called the elastic rebound theory which explains the recurrence of earthquakes along active faults.

(New Theory)Earthquakes explained by PPT Theory :

- Tectonic theory on the basis of plate motion can explain the type , distribution and intensity of Earthquake.
- Divergent Plate : shallow focus earthquakes and so Tsunami are not assoicated with divergent Plate Movements
- Convergent Plate associated with all three types of earthquakes in O-O and O-C collision(shallow, Intermediate and deep earthquake) but in C-C collision shallow earthquakes present

Most of earthquakes occur in the plate boundary regions; however, a few damaging earthquakes have occurred in the plate interior regions as well.

Type of Margin	Divergent	Convergent	Transform
Motion	Spreading	Subduction	Lateral sliding
Effect	Constructive (oceanic lithosphere created)	Destructive (oceanic lithosphere destroyed)	Conservative (lithosphere neither created or destroyed)
Topography	Ridge/Rift	Trench	No major effect
Volcanic activity?	Yes	Yes	No



Transform Plate : it Occurs when the two plates move parallel to each other in the same or opposite direction as the plates moves there is release of large amount of energy and hence the Transform Boundary related with Powerful Earthquakes . They Associated with Faults and Rift valleys

Eg San Andreas Fault Region in North West USA and Great East African Rift Valley .

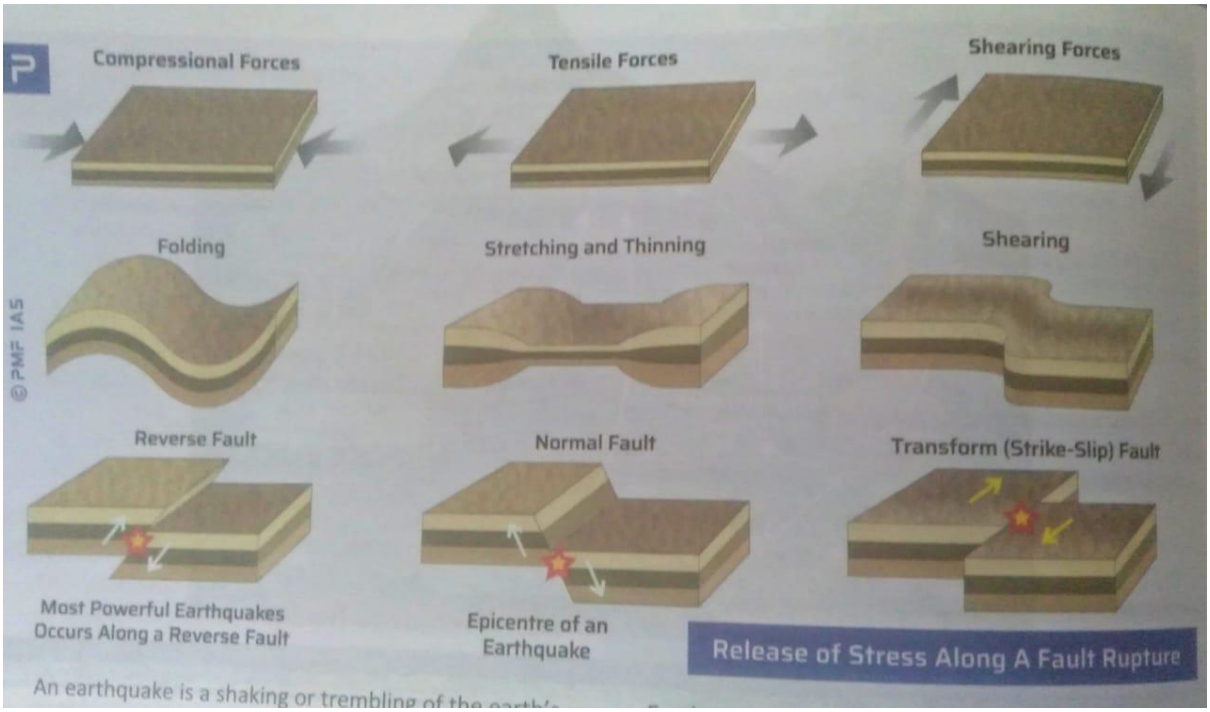
WHICH TYPES OF PLATE BOUNDARY RELATED WITH EARTHQUAKES

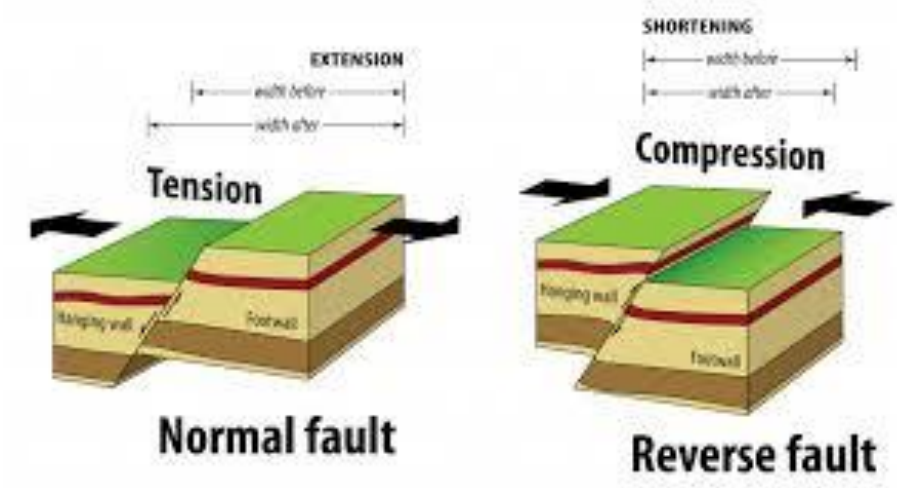
- **Convergent Plate Boundary**
- **Divergent Plate Boundary**
- **Transform Plate Boundary**

Keywords :

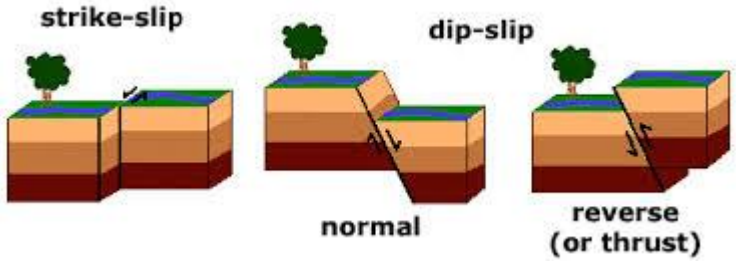
1 .FAULT AND DIP

- A fault is a fracture or rupture zone between two blocks of rock
- During an earthquake, the rock on one side of the fault suddenly slips with respect to the other
- Earthquakes is Release of Stress along a fault Zone
- The Horizontal and Vertical movement caused by endogenic forces result in the formation of faults, which cause isostatic disequilibrium and causes earthquakes.



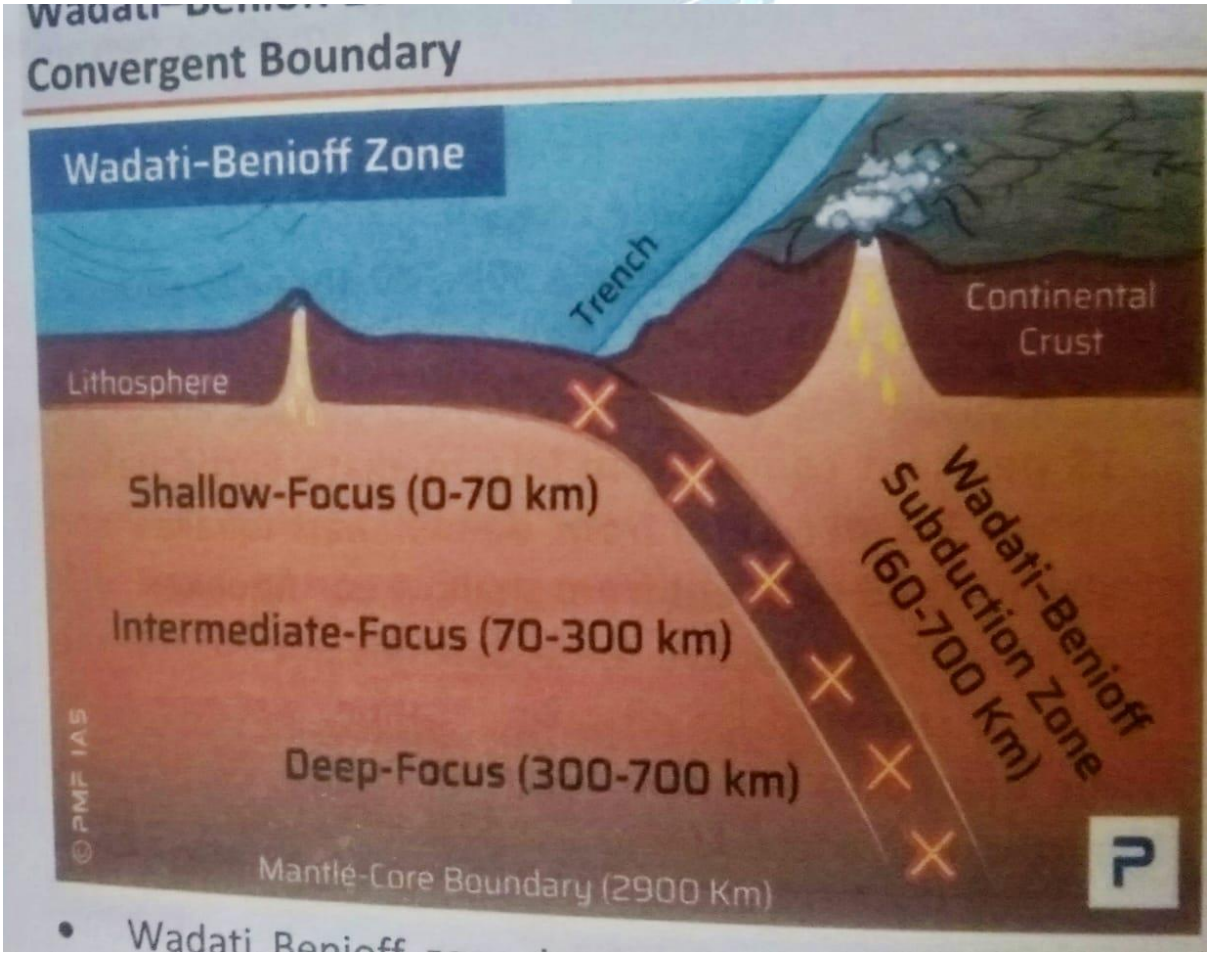


- angle of the fault with respect to the surface called dip.
- Normal and Reverse Fault called Dip Slip Faults



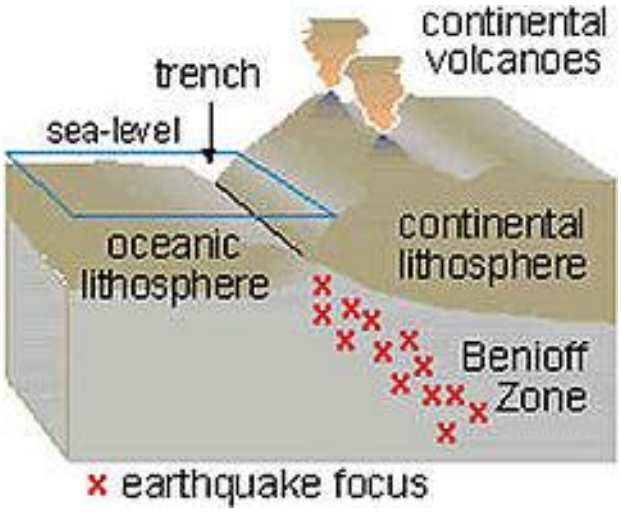
See Stress pattern: Shear Stress/ Tensional Stress/ Compression stress respectively in Strike Slip and Normal and Reverse Faults.

- **Reverse Faults Or Thrust Fault : Longest Earthquake(Large Rupture Or Crack Zone)-** Compressional stress generate earthquakes/ shortening crust
- **Normal Faults : Shorter Earthquakes (Small Rupture Or Crack Zone)**
- **Strike Slip Fault : Longer Earthquakes And Moderate Crack Zone**



❖ **Depth :**

- shallow-focus' earthquakes(less than 70 km);
- 'intermediate-depth' earthquakes(70 and 300 km);
- Deep-focus earthquakes 300 to 700 km)



Wadati Benioff Zone : (60 -700km)

- is subduction zone formed due to Convergent Boundary
- Here Earthquakes are common
- differential motion along the zone produces numerous earthquakes with different focus.
- created due to reverse thrust fault
- Ex : C- C convergent boundary in Himalayan Region
- created also in slip on faults within plate O-O and C-O convergent plate.
  Wadati–Benioff zone earthquakes develop beneath volcanic island arcs and continental margins above active subduction zones

Inter-plate & Intra-plate earthquakes

Earthquakes directly associated with forces acting along the plate boundaries are called "inter-plate" earthquakes. About 80% of the seismic energy is released by inter-plate earthquakes. In contrast, earthquakes which occur at rather large distances from the respective plate margins are called "intra-plate" earthquakes. These earthquakes can be large and because of their unexpectedness and infrequency can cause major damage.

2. Aseismic:

- A fault on which no earthquakes have been observed or area with no recod of earthquake.

3 . Seismic gap

- Sections of plate boundaries that have not ruptured in the recent past .
- an area in an earthquake prone region where there is below average release of seismic energy .

4 **Foreshock:**

- occur before main shock but relatively smaller .
- A relatively small tremor (or an earthquake) that commonly precedes a relatively large magnitude earthquake (called the "main shock"), by seconds to weeks or months and originates in or near the rupture zone of the main shock

5. Mainshock : large earthquakes in sequence

5. **Aftershock**: earthquake occur after mainshock but relatively smaller

- Focus/Hypocentre: Point inside the earth where the earthquake originates.
- Epicentre: Point on the earth's surface directly above the focus. It's the point that feels the earthquake waves first.

6 **Earthquake Swarm:**

- series of minor earthquakes, none of which identified as main shock, occurring in a limited area and time.
- Large number of small earthquakes may occur in a region for months without major earthquakes. Such Series of Earthquakes are called Earth quake Swarms .
- They occur in a localised region and over a period of time ranging from days, weeks to even months, without a clear sequence of foreshocks, main quakes and aftershocks
- Ex : Palghar and Amaravati low magnitude Earthquake swarms.
- Some believe it is related to groundwater levels and others attribute to tectonic activity . If groundwater is cause , the quakes may remain small. This phenomenon called Hydroseismicity , which is common across Deccan Plateau.
- Scientists still don't know whether these earthquakes are a result of seismic activity, hydro-seismicity due to water percolation post-monsoon, or magmatic activity in the region.

TYPES OF EARTHQUAKES

- Tectonic Earthquakes: Most common, caused by rock movement along fault planes. E.g., San Andreas Fault in California.
- Volcanic Earthquakes: Linked to volcanic activity, triggered by magma movement. E.g., Earthquakes around active volcanoes like Mount Vesuvius.
- Collapse Earthquakes: Minor quakes from sudden underground collapse in mining areas. E.g., Mining regions experiencing subsidence.
- Explosion Earthquakes: Human-induced seismic events from explosions. E.g., nuclear testing sites
- Reservoir-induced Earthquakes: Triggered by the weight of water in large dams. E.g., Reservoir induced seismicity near Koyna Dam (Maharashtra)

Main Cause Of Earthquakes :

- Fault Zones
- Movement of plates of earth crust or plate Tectonics (movement)
- Volcanic eruptions
- Folding and faulting of rocks
- Landslides.

- Human Induced Earthquakes are minor earthquakes that are caused by human activity like Mining, artificial lakes, Nuclear test Explosions, Dam and reservoirs creating Hydrostatic pressure or reservoir induced Seismicity earthquakes. 1967 Koyna Dam Earthquake In Maharashtra and Sichuan earthquake china

TYPES OF EARTHQUAKE WAVES

Body Waves: Emanate from the focus and traverse through the earth; travel only through the interior of the earth. They are of two types- Primary Waves (P-waves) and Secondary Waves (S-waves)

Surface Waves: Originate from the interaction of body waves with the surface; move along the earth's surface; recorded last of all the waves on on the seismograph; more destructive. They are of 2 types- Love waves (L-waves) and Rayleigh Waves (R-waves).

Speed of different waves: Primary Waves > Secondary Waves > Love Waves > Rayleigh Waves.

Type of Wave	Wav
P-Waves	Boc Lon (p vi pa th dir
S-Waves	Bo Tra (p vi perp to t dir
Love (L-Waves)	Surf Tra
Rayleigh (R-Waves)	S wav Trar Lon

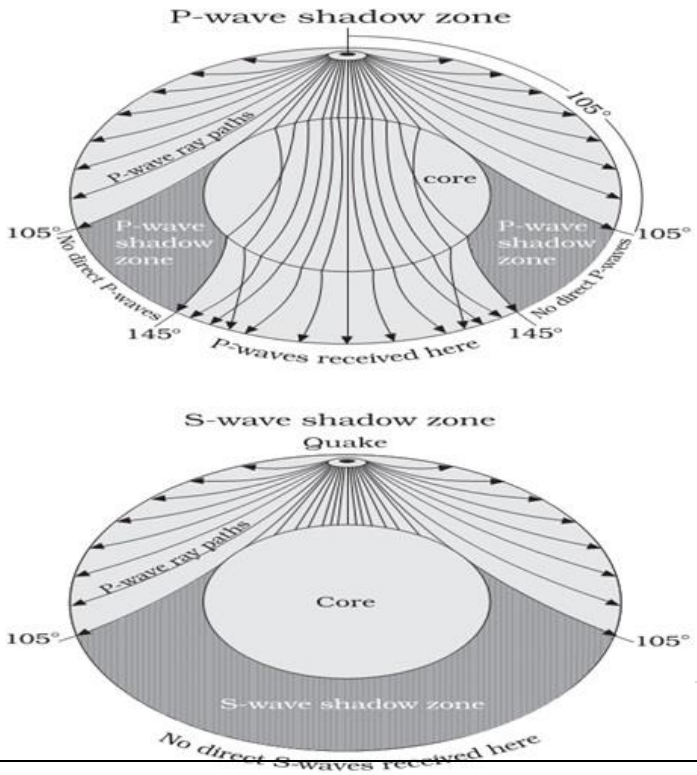


Figure 3.2 (a) and (b) : Earthquake Shadow Zones

Shadow Zone :

- some specific areas where the waves are not reported. Such a zone is called the 'shadow zone'
- It is an area on the earth's surface where certain earthquake waves aren't detected.
- The study of different events reveals that for each earthquake, there exists an altogether different shadow zone.

Why do earthquakes waves develop shadow zone ?

- Because P and S waves follow a curved path inside the earth due to increasing capacity.
- The change in seismic velocity between different layers cause refraction owing to Snell Law - Laws of refraction.

Key Facts of Shadow Zone :

- Seismographs within 105° of the epicenter detect both P and S-waves.
- The entire zone beyond 105° does not receive S-waves.
- Beyond 145°, only P-waves are recorded.
- The zone between 105° and 145° is the shadow zone for both waves;
- S-wave shadow zone (covering 40% of the earth's surface) covers a larger area.

Explanation of Body Waves :

Primary Waves :

- p-waves

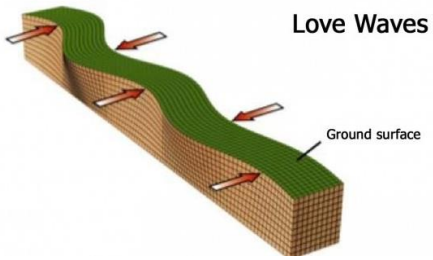
- push- type wave
- Longitudinal
- Compressional waves
- P waves are fastest but of least intensity
- Velocity of p waves in Solid (a higher velocity) > Liquids> Gases (lowest velocity of moving
- They are similar to sound waves, i.e, they are longitudinal waves, in which particle movement is in the same direction of wave propagation.
- They travel through solid, liquid and gaseous materials.
- undergo compression and refraction
- They create density differences in the earth material leading to stretching and squeezing.
- shadow zone region: Angle between 105 and 145 degree.
- This reveal the existence of a solid inner core

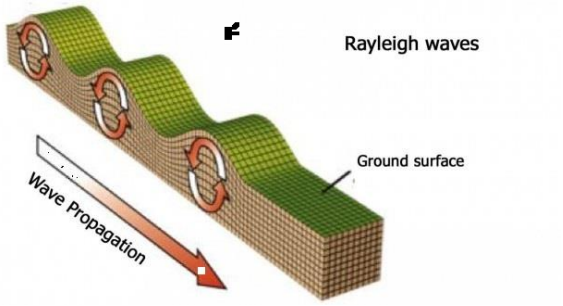
Secondary Waves :

- **s-waves**
- **Transverse**
- **distortional waves**
- pull or shake waves
- They are transverse waves in which directions of particle movement and wave propagation are perpendicular to each other.
- They are slower than primary waves and can pass only through solid materials.
- Not passes through liquids or gaseous mediums.
- So it helps in understanding that Outer core is liquid in nature and therefore S wave Shadow Zone is Greater than P Wave Shadow Zone

SURFACE WAVES

- Long Period waves
- L waves
- When the body waves interact with surface rocks, a new set of waves is generated called as surface waves.
- These waves move along the earth surface.
- Last to report on seismographs.
- More destructive , cause displacement of rocks
- Surface waves are also transverse waves in which particle movement is perpendicular to the wave propagation.
- Hence, they create crests and troughs in the material through which they pass.
- Surface waves are considered to be the most damaging waves.
- Two common surface waves are Love waves and Rayleigh waves.





Rayleigh waves:

- Lord Rayleigh, the English physicist, who predicted their existence in 1885
- Slower than Love waves
- Cause the ground to shake in an elliptical pattern.
- These waves follow an elliptical motion parallel to wave propogation.
- Because it rolls, it moves the ground up and down and side-to-side in the same direction that the wave is moving.
- Rayleigh waves, which cause both vertical and horizontal rolling motion.
- Most of the shaking felt from an earthquake is due to the Rayleigh wave, which can be much larger than the other waves.

Love waves

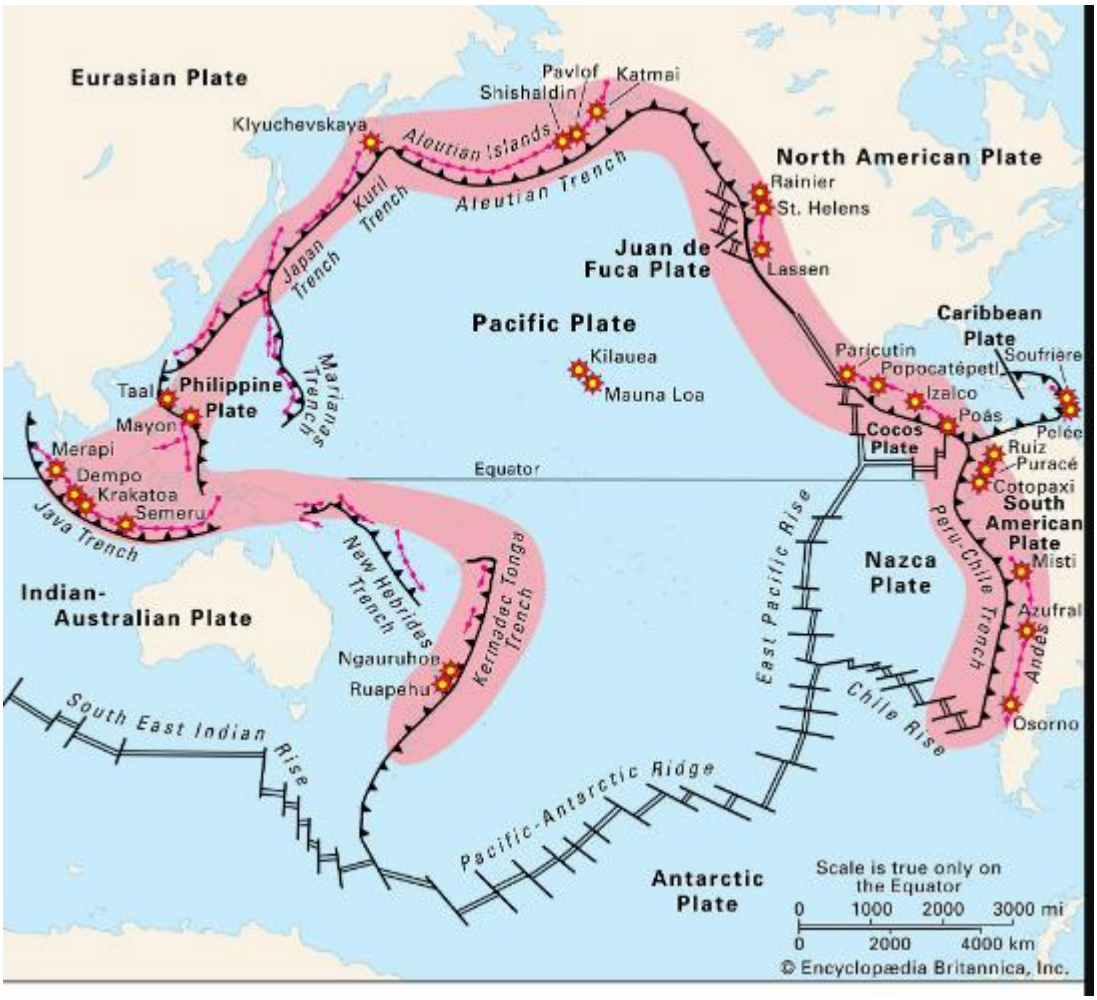
- **coined by** AEH Love, a British mathematician (1911).
- fastest surface wave and moves the ground from side-to-side
- Sideways motion perpendicular/ transverse to the direction of propagation
- Faster than rayleigh waves
- No vertical displacement , , means horizontal motion/ shifting of the Earth during earthquake

DISTRIBUTION OF EARTHQUAKES

Most of the Earthquakes Occur in

- Earthquakes are generally associated with the weaker and isostatically disturbed areas of the globe
- The Zone of Young Mountains
- The Zone of Faulting and Fracturing
- The Zones representing the junction of Continental and Oceanic Margins.
- The Zones of Active Volcanoes
- Along Different Plate Boundaries

- Earthquakes have a definite distribution pattern. There are three major belts in the world which are frequented by earthquakes of varying intensities. These belts are as under:
- Mid oceanic ridges (Eg: Atlantic ocean); AlpineHimalayan system and the Pacific Ocean Ring of Fire.
- Earthquakes in mid-oceanic ridge areas are shallow, while those along the Alpine-Himalayan belt and Pacific rim are deep-seated.



The Pacific Ring of Fire is known for its intense volcanic and seismic activity. Discuss the factors responsible for the high level of tectonic activity in this region and its significance in global geology. (15 Marks, 250 Words)

ABOUT **CIRCUM-PACIFIC BELT REGION :**

- Called As Ring of Fire; Formed Due to mainly Convergent Plate Boundary
- U shaped or Horseshoe shaped approx 40000km
- subduction zone so intense volcanoes and earthquakes formed here.
- account for more than 60 percent earthquakes of the world
- isostatically unstable and weaker region
- Pacific oceanic plate sub ducts below the American plates
- Japan alone experiences about 1500 earthquakes per year.
- young fold mountains : Andes, Rockies
- Volcanic Islands and volcanic islands chain/ festoons formed .

- Kamchatka, Sakhalin, Japan, Philippines, Kuril islands, Aluentian Islands
- trenches formed in pacific oceans
- Region Included : New zealand-NewGuinea-Indoneisa-Philippines- Japan(65% alone in Honshu Islands)-Kamchataka area-East siberia-Aleutian Islands- Alaska, North america-SanAndreas fault California, Rockies-Andes-Antartica.
- Formation of Hot Spots: The Ring of Fire is also home to hot spots, areas deep within the Earth's mantle from which heat rises

FACTORS RESPONSIBLE FOR TECTONIC ACTIVITY :

- Tectonic Plate Boundaries- The Ring of Fire coincides with the boundaries of several tectonic plates, including the Pacific, Cocos, Nazca, Philippine, North American, Indian-Australian, and others
- These plates are either colliding, diverging, or sliding past one another leading to stress and strain in the Earth's crust, resulting in earthquakes and volcanic activity.
- Hotspots: Presence of hotspots in this region causes an upwelling of hot mantle material that can melt the overlying crust and create volcanic activity. The Hawaiian Islands, for example, are the result of a hotspot beneath the Pacific Plate.

- As the Circum-Pacific Belt harbors the majority of global Volcanic eruptions & Earthquakes, it holds immense significance regarding the study of the earth's interior
- **Mineral Resources:** Volcanic activity in the Ring of Fire can bring valuable mineral resources to the surface, making this region a hotspot for mining and resource extraction
  Scientific Research: The Ring of Fire is a hotspot for scientific research in geology, seismology, and volcanology.

2. THE MID-ATLANTIC RIDGE BELT:

- This belt is characterised by the sea floor spreading which is the main cause of the occurrence of earthquakes in it.
- It records moderate earthquakes due to spreading zone of divergent plates.
- thus sea floor spreading and fissure volcanic eruptions cause moderate intensity earthquakes in this region.

3. THE MID-CONTINENTAL BELT: 11%-20%

- Include Alpide mountains belts region (extends from Mediterranean region, eastward through Turkey, North Africa and Eastern Africa , Iran, and Himalayas and Myanmar in the East till Andaman Region.
- Belt represent weaker zone of fold mountains

- **Major earthquakes of World : Megathrust earthquakes**

S. No.	Date	Location	Magnitude

1.	1960	Valdivia, Chile	9.5
2.	Dec 2004	Sumatra, Indonesia	9.3
3.	1964	Alaska, USA	9.2
4.	1952	Kamchatka, Russia	9.0
5.	1700	Cascadia Subduction Zone (Pacific Ocean rim)	9.0

Causes of Bhuj Earthquake 26 Jan 2001

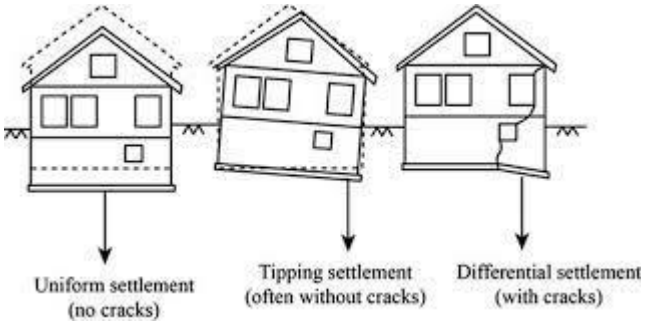
- **Gujarat is located 300 to 400 km from the boundary of the Indian and Eurasian Plates.**
- **This area faced roughly west-east rifting trend during the break up of Gondwana in the Jurassic Period.**
- **Continuous collision shorting the crust and Kachchh region reactivating the existing rift faults and developing new low angle thrust faults under the surface**
- The 2001 Gujarat earthquake was caused by movement on a previously unknown south-dipping fault, trending parallel to the inferred rift structures

EFFECTS OF EARTHQUAKES:

Earthquake is a natural hazard. The following are the immediate hazardous effects of earthquake:

(i) Ground Shaking: the vibration of the ground during an earthquake. Ground shaking is caused by body waves and surface waves.

(ii) Differential ground settlement : Differential settlement occurs when one part of a structure's foundation settles more, or faster, than the other



(iii) Land and mud slides

(iv) Soil liquefaction: is a phenomenon in which the strength and stiffness of a soil is reduced by earthquake shaking

(v) Ground lurching: horizontal shifting : irregular cracks in the ground surface due to seismic activity

(vi) Avalanches : a very large amount of snow that slides quickly down the side of a mountain (The first six listed above have some bearings upon landforms)

(vii) Ground displacement : It is the vertical shifting of the ground which can result in the rising or sinking of the ground

(viii) Floods from dam and levee failures

(ix) Fires

(x) Structural collapse : When internal load bearing structural elements fail, a building will collapse into itself and exterior walls are pulled into the falling structure

(xi) Falling objects

(xii) Tsunami -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.

Focus Pre Disaster : PREPAREDNESS MEASURES

1. Community preparedness
2. Public Education
3. Planning
4. Post Disaster Assistance Needs
5. Earthquake Response Plan

THE SIX PILLARS OF EARTHQUAKE MANAGEMENT:

They will help to:

1. Ensure the incorporation of earthquake resistant design features for the construction of new structures.
2. Facilitate selective strengthening and seismic retrofitting of existing priority and lifeline structures in earthquake-prone areas.
3. Improve the compliance regime through appropriate regulation and enforcement.
4. Improve the awareness and preparedness of all stakeholders.
5. Introduce appropriate capacity development interventions for effective earthquake management (including education, training, R&D, and documentation).
6. Strengthen the emergency response capability in earthquake-prone areas

EARTH QUAKE HAZARD MITIGATION

- Focus should be on disaster preparedness and mitigation rather than curative measures.
- Establishing Earthquakes monitoring centres/ seismological centres for regular monitoring and information among the people in the vulnerable areas.
- Preparing a vulnerability map of the country and dissemination of vulnerability risk information among the people and educating the, about the ways and means minimising the adverse impact of disasters.
- Modifying house type and buildings design in the vulnerable areas.

- Discouraging construction of high rise buildings, large industrial establishments and big urban centres in such areas.
- Enhancing the safety of dams and reservoirs
- Scientific Seismic Zonation and seismic micro zonation is needed.
- Focus should be more on non structural measures and inter agency cooperation.
- Investing in DRR : structural and non structural measures
- Need safety audit
- In terms of capacity development training and awareness generation is needed.
- Mock drills , community based disaster managements needed
- Empowering women, marginalised and persons with disabilities.

OPINIONS FOR EARTHQUAKE MITIGATION

- Seismic and Vulnerability map at micro level must be prepared , which will help the state to be better prepared for all the disasters.
- Integration of development plans with disaster mgmt plans is must.
- Mock drills, strict Implementation of Building codes, Professional accountability for certification of building safety with architect and safety of critical building like school, hospitals are needed at all levels to ensure preparedness and readiness.
- Media needs to be sensitised and made partner in mitigation activities
- Capacity building of community and vulnerable to enhance their capability to cope with disaster, as they are first responders

Prepare Answers ?

1. Why Earthquakes are Common in Indonesia

2 Why Earthquakes are Common in Japan

3 Why Earthquakes are Common in Himalayas and uncommon in Western Ghats

REASONS WHY EARTHQUAKES ARE COMMON IN INDONESIA

- **Indonesia located in the pacific ring of fire**
- Isosatic disequlibrium- tectonically unstable and weaker region- fault lines
- **Prone to Shallow deptthEarthquakes and volcanic eruptions**
- **Interaction of Major Tectonic Plates**
- **Located in four tectonics plates**
- it its located on tri junction of three major plates : Indo Australia Plate, Part of Asian Plate (Sunda Plate) and Pacific Plate and Presence of minor Burma Plate and this convergent collision helps to form Sumatra, Java, Bali, Bornea, celebas , Lombak Island
- All this is example of O- O Convergence so numerous earthquakes, Volcanoes and Tsunami region and deepest trench located here is java trench in Indian ocean .
- poor infrastructure, and historical patterns of seismic activity, all contribute significantly to its high vulnerability to earthquakes.

❖ Densely Populated Region - Tropical Country- Intense rainfall - Intense weathering- increase soil Environmental Effects of Deforestation in Indonesia –

- Illegal logging, slash and burn cultivation
- Soil degradation , Soil erosion, land degradation, soil lose its binding capacity

- landslides