



MODULE-1

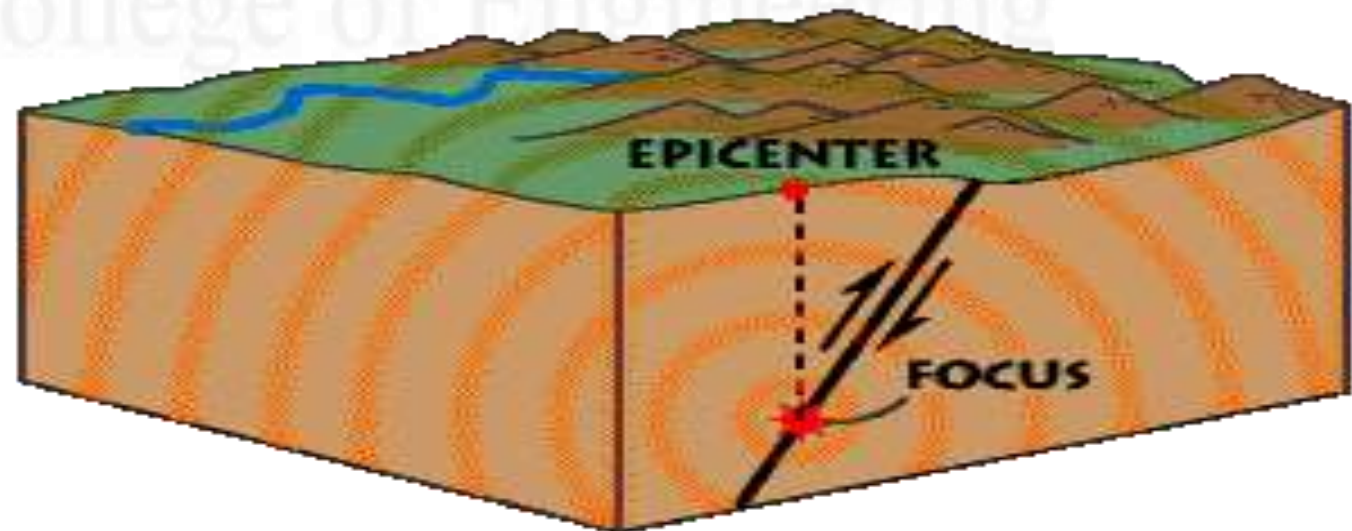
Introduction, scope of earth science in Engineering, Geohazards and disasters, Mitigation and management

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

EARTHQUAKE

- These are vibrations induced in the earth's crust that virtually shake up or gives a jerking blow/movements to a part of the crust.
- These are extremely short-term movements rarely exceeding few minutes and highly variable in their intensity and distribution.

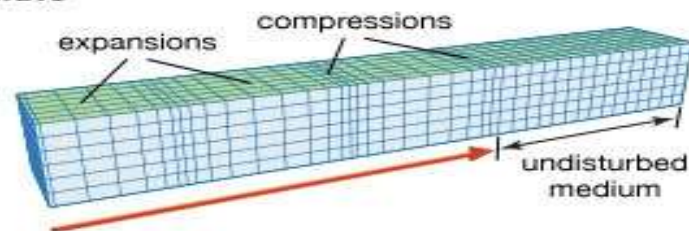
- Focus or **Hypocentre**: The place from which an earthquake starts is known as focus or hypocentre. It is the point below the earth's surface where the disturbance is commonly in the form of displacement or faulting of rocks.
- **Epicentre**: The point or place on the surface vertically above the focus of an earthquake is termed as epicentre of that particular earthquake. It is a place on the earth where the earthquake disturbances reach first and do the maximum damage.



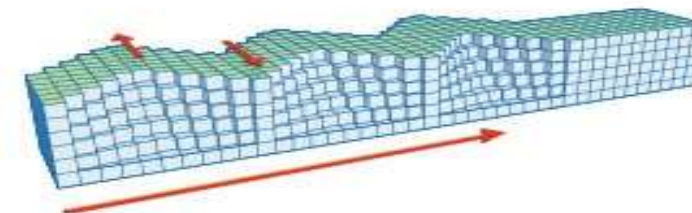
- **Seismic waves:** These are elastic waves characterized by velocity, frequency and amplitude.
- Seismic waves in the earth crust exceed up to 7km/sec. However, the velocity depends upon the type of wave and the nature of the medium in which it travels.
- Seismic waves are classed as body and surface waves.
- From the focus of an earthquake, the two types of body waves (P and S), and two types of surface waves (Love and Rayleigh, which are S-waves trapped near the surface) radiate in all directions.

Main types of seismic waves

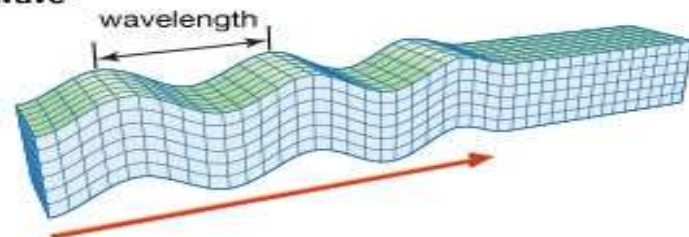
P wave



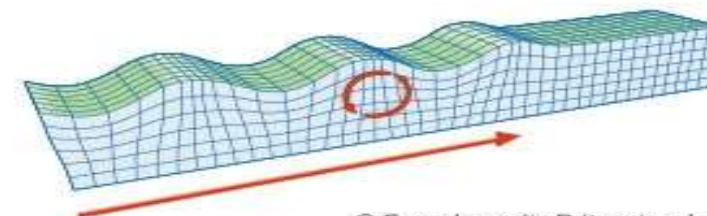
Love wave



S wave



Rayleigh wave

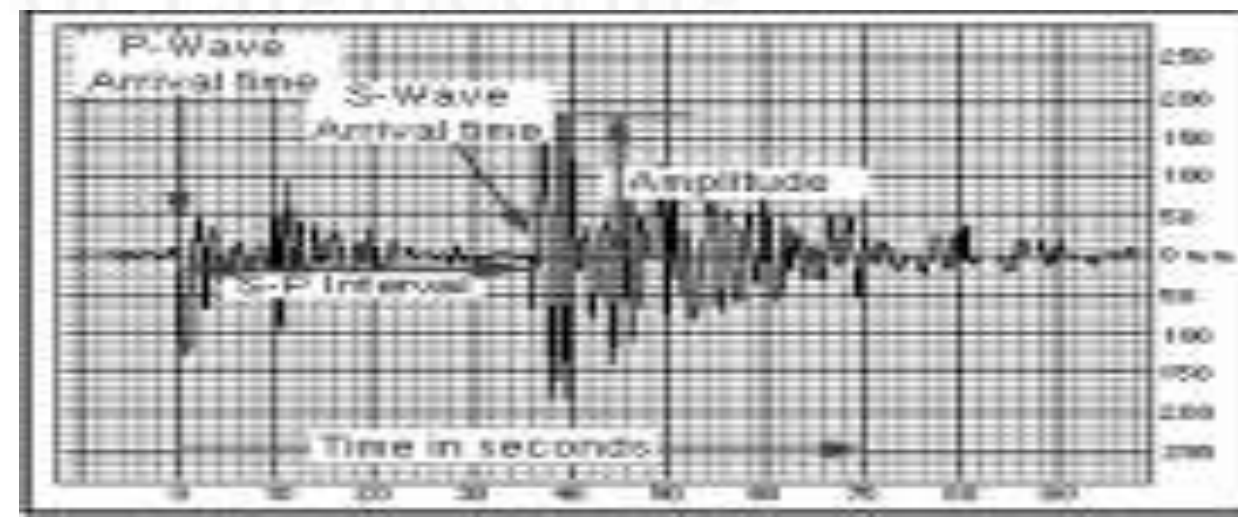


- **1.primary/p-waves** : Where the motion of particles is parallel to the direction of propagation of the wave. They can travel in all the 3 states of matter (solid, liquid & gases). Their velocity is 5-8 km per sec. Transverse/secondary/shear/S-waves: Where the motion of the particles in a medium is perpendicular to the direction of propagation.
- These waves are transmitted only in solids but not in fluids. Their velocity is 3-5 km per sec.
- **2. Surface waves**: In this category there are two types known as Rayleigh waves & the love waves.
- In Rayleigh waves the motion is elliptical (combination of p & s waves).
- These waves propagate along the surface, rather than through the body of the planet, and thus most damage from earthquake shaking is caused by Love or Rayleigh waves.

EARTHQUAKE MAGNITUDE AND INTENSITY

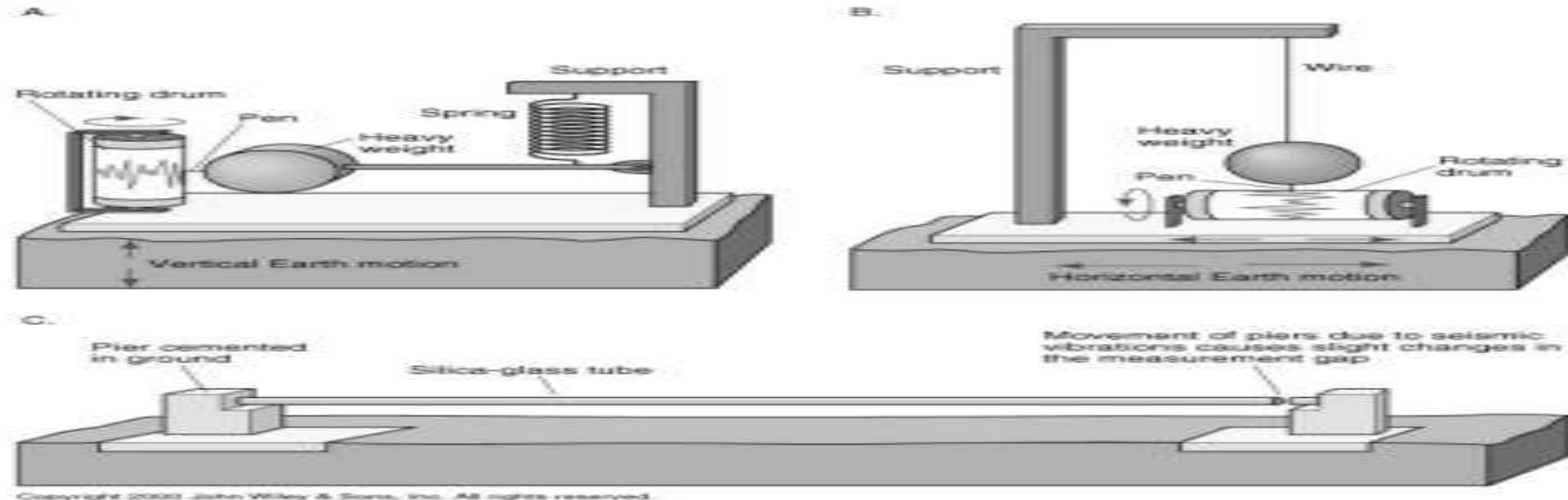
- Magnitude of an earthquake is an instrumental rating of the energy (the size or strength of the quake) released by it.
- Magnitude varies with the wave amplitude of an earthquake recorded by a seismograph.
- By knowing the distance from a seismograph station to the epicenter and the maximum amplitude recorded, an empirical quantitative rating is estimated .
- Intensity of an earthquake is a numerical index describing the degree of ground shaking and effects on life and property at any given locality.
- Intensity is essentially a function of an earthquake and local geological conditions. Intensity is severe at and around the epicenter area and decreases away from it.

- **Two scales of intensities are in use.**
- I) Rossi Forrel Scale: which divides all the shocks into 10 arbitrary types beginning from one and ending with ten (imperceptible, feeble, very slight, slight, strong, very strong, severe & destructive etc).
- II) Mercalli scale: suggests 12 types one (very weak) to twelve (catastrophic). In each scale a number of intensity mentioned with an earthquake denotes its rating on the basis of 'effects' observed during and after the earthquake.
- **Isoseismals:** These are lines passing through values of same intensity in a particular earthquake record. The isoseismal record of an earthquake may show closely spaced or widely spaced lines and they may be regular or irregular in nature.



- **SEISMOGRAPH:**

- It is the instrument designed to record earth motion set up by seismic waves. A seismograph may be designed to record vertical, horizontal or both components of ground motion. The essential part of such a seismograph is a pendulum which swings in a fixed plane either vertically (up & down Figure A) or horizontally (to & fro Figure B) during an earthquake. In normal conditions pendulum remains at rest.



CAUSES OF EARTHQUAKE (Origin of Earthquakes)

- Non-tectonic: These are caused either by volcanic eruption or by collapse of ground . Generally both of these types are felt locally. The volcanic earthquake is caused due to jerks or vibrations induced in the ground due to volcanic eruption of lava/magma and due to sudden blow/ explosion of gases & lava. The collapse earthquake is of very local nature and is rare.
- Tectonic: These are the most common and most destructive events. It is broadly agreed that these are caused by displacement of blocks of rocks of the earth crust. The cause of tectonic earthquake is explained by following theories.

EFFECTS OF EARTHQUAKE:

- **Primary Effects:** These include all such effects that are directly related to the cause of origin of an earthquake. The tectonic earthquakes are often responsible for producing many changes in the geological structure of an area.
 - ☐ Creation of slopes or scarps, fissures, wrapping of strata.
 - ☐ Emergence or subsidence of coastlines
 - ☐ Change in the course of river; Origin of new springs.

- **Secondary Effects:** All those effects which are related to passage of seismic waves and associated shaking motion of the ground during an earthquake are grouped as secondary effects.
1. Destruction of various civil engineering constructions like dams, bridges, tunnels, road and railway tracks.
 2. Causing landslides, subsidence of land mass and unstable conditions along hill slopes. Landslides may cause blocking of roads and railway lines in some places.
 3. Submarine earthquakes cause tsunamis, which are giant tidal waves, when they dash against the shores they lead to destruction of coastal lines and occurrence of landslides, earthquakes and floods.
 4. Faults/Fractures on the earth crust.
 5. Change in the course of river, formation of waterfalls, change in ground water levels.
 6. Electric short circuits and fire.
 7. Huge loss of economy that is incurred for rehabilitation, medical aid and reconstruction
 8. Loss of life and distress among people.

- **SEISMIC ZONES:** A seismic zone is a region in which the rate of seismic activity remains fairly consistent. This may mean that seismic activity is incredibly rare, or that is extremely common.
- Most high-activity seismic zones are located along fault zones, regions of the earth's crust which are prone to seismic activity.
- Fault zones often occur where continental plates meet, but they can also be found around volcanoes.
- A major fault zone in North America far from any plate boundaries is caused by a huge bubble of magma under the Earth's crust which periodically bubbles up into an explosive volcanic eruption.

Distribution of earthquake:

- A record of past occurrence of earth quake reveals that earthquake are common features in some regions broadly speaking shocks of the past had been largely confined to two large geographic belts. The circum pacific belt and the Mediterranean belt.
- The circum pacific belt; which forms a ring closing North America, most of Asia and Europe accounts for the largest number of all types of earth quake (about 70%).
- Mediterranean Belt; enclosing India, Arabia, Africa, S.Africa and Australia. About 21% of earth quake originated in areas lying in this belt. The distribution pattern of past earth quake
- shows that most of these above 50% occurred in the youthful mountain system areas of the world such as Andes, Himalayas, and coastal ranges of United States.

Indian continent is divided into (based on earthquakes) three zones:

- Zone of Maximum (severe) Intensity: - Which comprises the Northeastern regions, especially the folded chains of Himalayas, geographically this area covers Assam, Himachal Pradesh, Kashmir including Leh, Ladakh, U.P, Uttaranchal, Delhi and Nagaland. Past 100 years earthquake history taken in to account.
- Zone of Intermediate (moderate) Intensity: - Which covers the regions of indo-Gangetic basin after observing past 100 years earthquake records showing moderate earthquake intensity.
- This zone comprises the remaining southern areas of Punjab, Haryana, U.P., West Bengal and part of Bihar, Orrisa, Northern part of Gujarat, M.P. and Maharashtra.
- Zone of Minimum (slight) Intensity: - It is stable land with respect to earthquake and comprises peninsular India includes Madhya Pradesh, Orissa, Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu and Kerala.

- **EARTHQUAKE RESISTANT STRUCTURES:**
- To build Earthquake resistant structures it is necessary to determine the probable intensity and magnitude of earthquake shocks in the area concerned. The history and records of previous earthquakes and the knowledge of local geology are of help in this connection.
- The precautions have to be followed to minimize the danger of collapse, failure of buildings during and after the shock.
- 1. The foundation
 - ☐ The structures built on loose soil or sediments or weak rocks will have to withstand greater shocks than those founded on solid hard rock.
 - ☐ The foundations for concrete and masonry buildings should be excavated to the same level throughout the building and should be of continuous type.
 - ☐ The foundations of costly structures should be carried down to rest on solid rock.
 - ☐ The structures should be thoroughly tiled up with the foundations by introducing keys or reinforcement to offer maximum resistance against sliding at that level.

- **The Body**

- ☐ The walls should be as light in weight as possible and made up of wood or light weight concrete.
- Stronger and resistant walls should be designed with reinforced concrete rather than plain concrete.
- ☐ Continuity of cross walls should be maintained.
- ☐ In masonry walls keys should be inserted in a proper style so that danger of sliding apart the horizontal joints is minimized.

- **The Roofs**

- ☐ Flat, RCC roofs gives greater resistance to buildings against shocks.
- ☐ Materials like slate, tiles and corrugated sheets will help to slip lateral stresses. The use of such materials has to be avoided.
- ☐ Projections above or beyond the roof level, should be avoided.

- ☐ Uniform height should be given to the buildings.
- ☐ Architectural fancies like domes, arches, parapets should be avoided.
- ☐ Taller structures should be avoided.

Earthquake prediction:

- Enormous devastations and the loss of many human lives caused by earthquake present the problem how to predict and suppress/prevent them.
- It involves the prediction of the place, the force and the time of the earthquake. Many predictions so far have been unsuccessful.
- However, attempts can be made by studying the elastic properties of the earth's crust, recording the seismicity and preparing isoseismal maps and demarcating seismic zones (Hazard zoning maps).
- Records on animal (grazing animals and reptiles) behavior are also important for prediction of earthquake.

TSUNAMI

- Tsunami is long wavelength seismic sea waves generated by the sudden displacement of the seafloor.
- The name is of Japanese origin, meaning “harbor wave. Tsunami may rise unexpectedly out of the ocean and sweep over coastal communities, killing hundreds of people and causing millions of dollars in damage.
- Such events occurred in 1946, 1960, 1964, 1992, 1993, and 1998 in coastal Pacific areas.
- The December 2004 tsunami following a magnitude 9.0–9.2 earthquake off the coast of Sumatra in the Indian Ocean killed approximately 300,000 people, making it the most destructive tsunami known in history.
- The sudden displacement of this volume of undersea floor displaced huge volumes of water and generated the most destructive tsunami ever recorded.

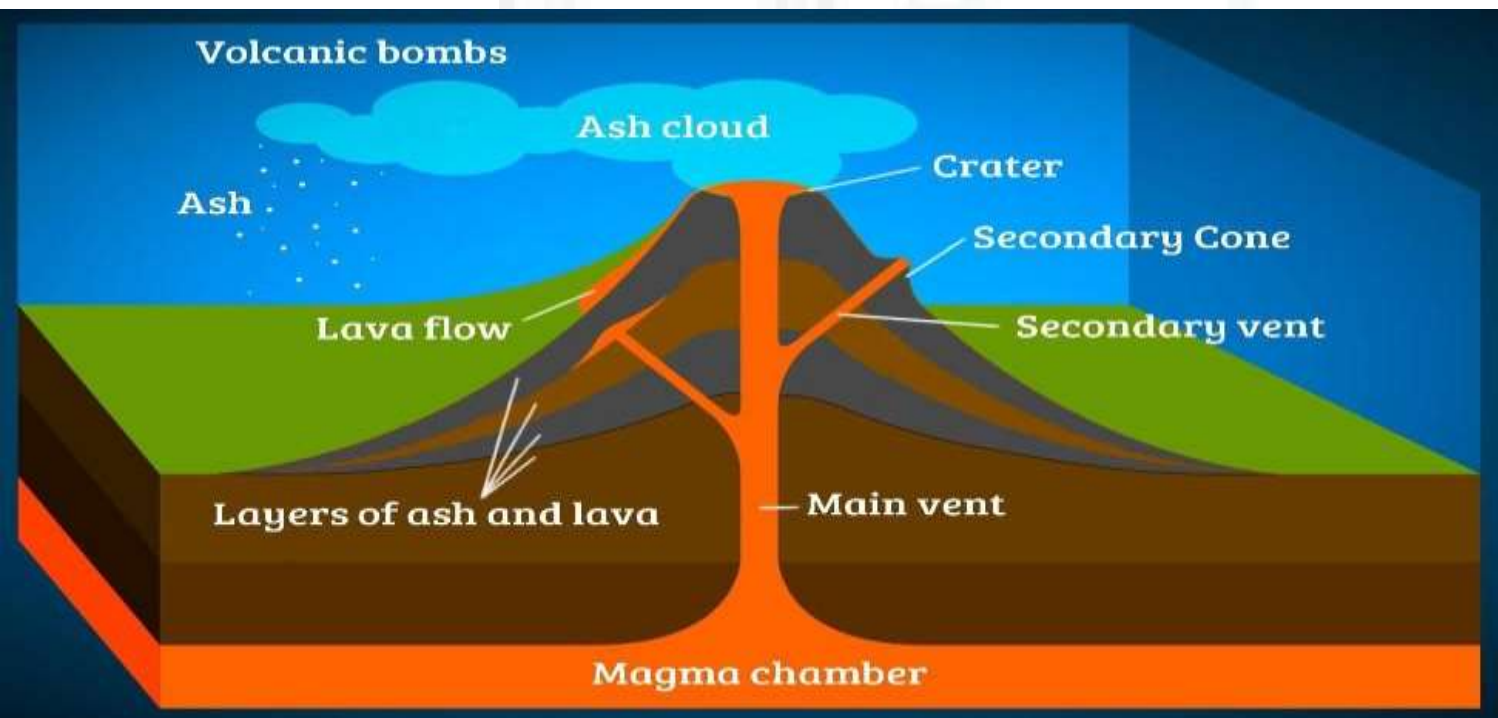
Movement of Tsunami

- Tsunamis are waves with exceptionally large distances between individual crests, and they move like other waves across the ocean.
- Wavelength is defined as the distance between crests, wave-height as the vertical distance from the crest to the bottom of the trough, and the amplitude as one-half of the wave height.
- Most ocean waves have wavelengths of 300 feet (100 m) or less; tsunami are exceptional in that they have wavelengths that can be 120 miles (200 km) or greater.
- Normal ocean waves travel at less than 55 miles per hour (90 km/hr), whereas many tsunami travel at 500 to 600 miles per hour (800 to 950 km/hr) Tsunami have long wavelengths,

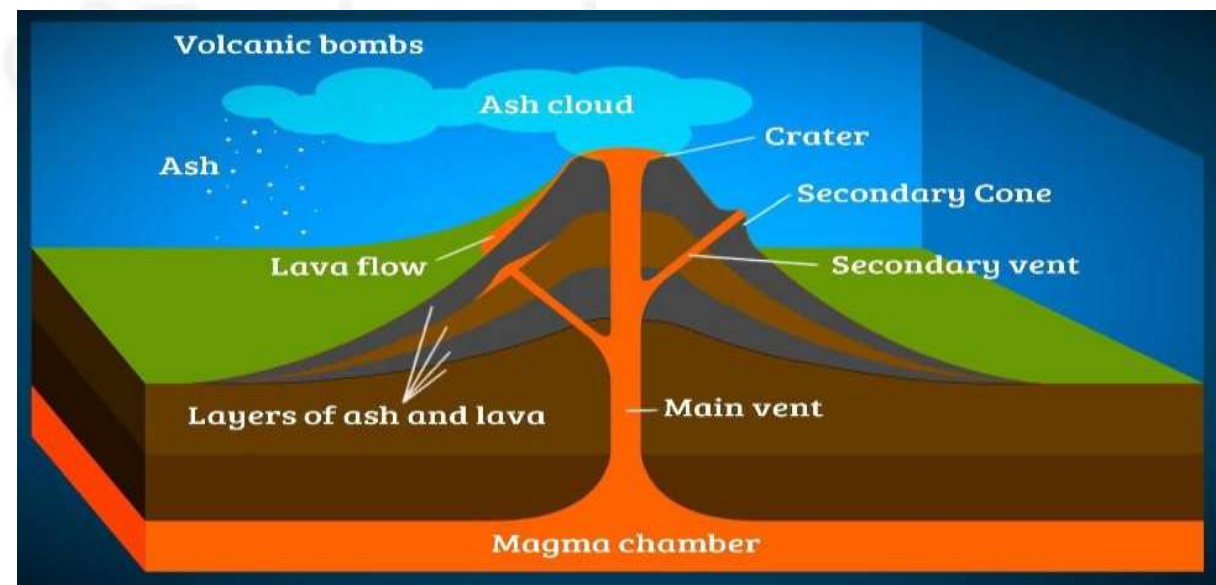
Effects:

- ☐ The amount of energy and water contained in a huge tsunami can cause extreme destruction when it strikes land.
- ☐ The initial wave of a huge tsunami is extremely tall; however, most damage is not sustained by this wave. Most of the damage is caused by the huge mass of water behind the initial wavefront, as the height of the sea keeps rising fast and floods powerfully into the coastal area.
- ☐ It is the power behind the waves, the endless rushing water that causes devastation and loss of life. When the giant breaking waves of a tsunami batter the shoreline, they can destroy everything in their path.
 - ☐ Destruction is caused by two mechanisms: the smashing force of a wall of water traveling at high speed, and the destructive power of a large volume of water draining off the land and carrying all with it, even if the wave did not look large.
- ☐ Objects and buildings are destroyed by the sheer weight of the water, often reduced to skeletal foundations and exposed bedrock. Large objects such as ships and boulders can be carried several miles inland before the tsunami subsides.
- ☐ Tsunami waves destroy boats, buildings, bridges, cars, trees, telephone lines, power lines - and just about anything else in their way.
- ☐ Once the tsunami waves have knocked down infrastructure on the shore they may continue to travel for several miles inland, sweeping away more trees, buildings, cars and other man made equipment. Small islands hit by a tsunami are left unrecognizable.

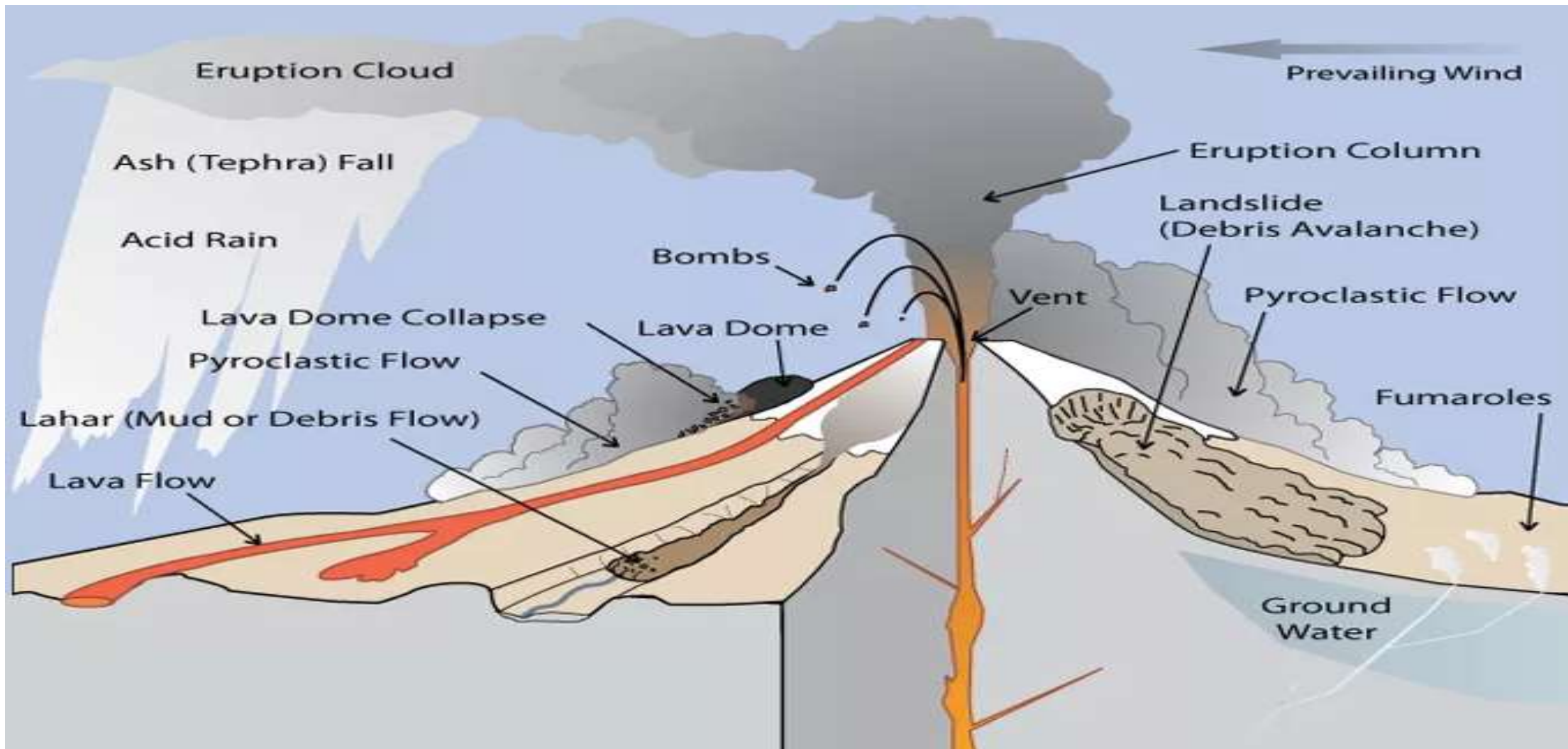
VOLCANIC ERUPTIONS



- The term volcano is derived from a Roman deity of fire, *Vulcan*.
- A volcano is most commonly a conical hill or mountain built around a vent that connects with reservoirs of molten rock below the surface of the Earth.
- The term *volcano* also refers to the opening or vent through which the molten rock and associated gases are expelled.
- The parental material of the hot volcano products is called as *magma*



- **Typical Volcano**
- A typical volcano has a vertical pipe.
- A communication between surface of the earth and the interior mass of magma or lava.
- It is generally conical in shape.
- It is the passage for lava hot gasses and fragments of rocks when the volcano erupts. The mouth of the volcano is called as "crater".
- It is funnel shaped. When the crater is wide it is called "Caldera", and it is formed due to violent explosion.
- Resulting in the blowing up of the summit of the volcanic cone or due to subsidence or collapse.
- The mountain shape of a volcano is due to the accumulation of lava and other material that come out of it.

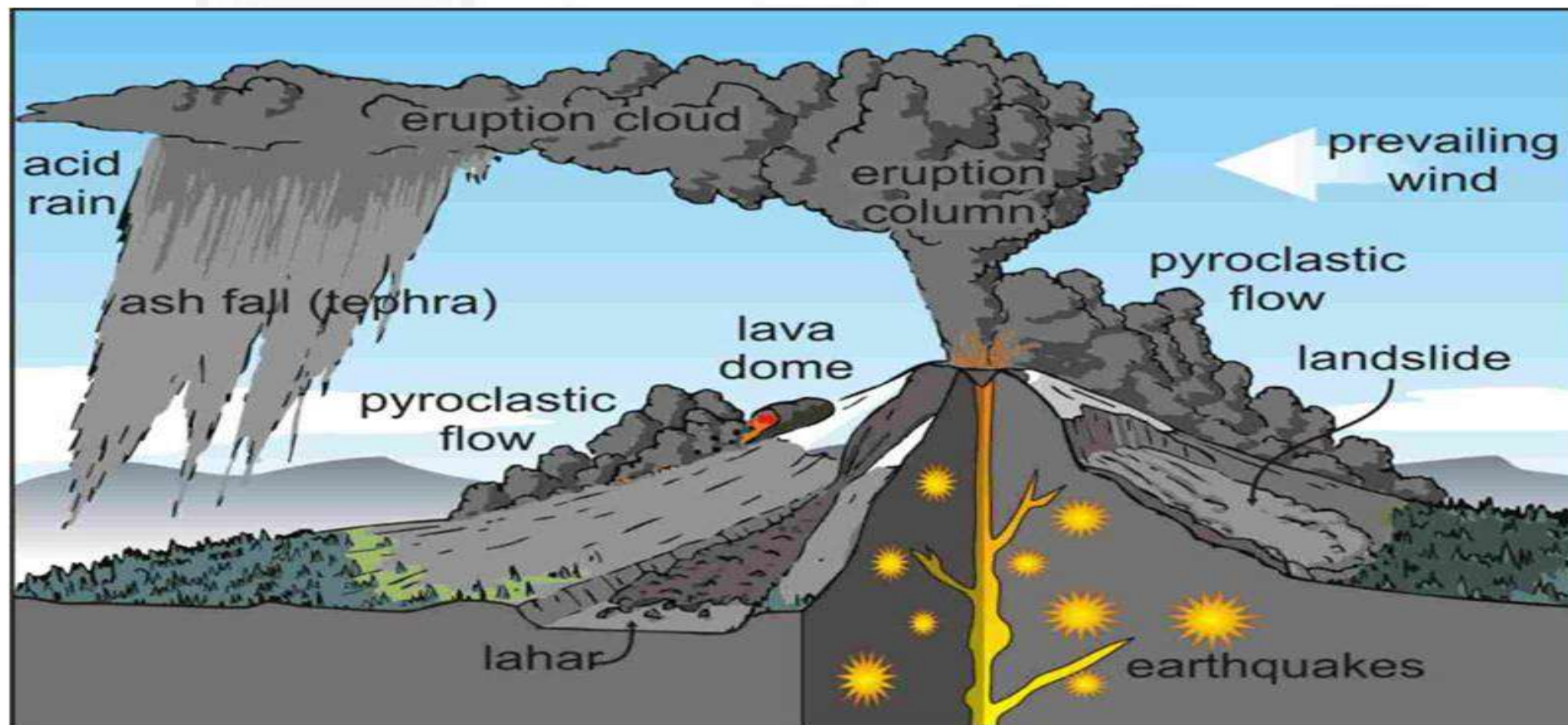


- The material which are thrown out or erupted by a volcano consist generally of all the three phases of the matter i.e., solid, liquid and gases
- **Solid materials** (Pyroclasts): These are solid materials thrown out by the pressure of the rising lava generally of country rocks. Pyroclasts consists of fragments of different sizes. The biggest fragments formed as "**Volcanic blocks**" (>32mm) accumulates near the crater. Where as those with a size between walnut and pea known as **cinders** or **lapilli**'s are thrown further away. The finest particles are called as volcanic dust



The bulk of the material erupted from volcanoes in the form of a hot, molten, plastic liquid is called as lava

Gases. Gases are generally the first to reach the surface and acquire great heights over a volcano. The most dominant gas is steam; carbon dioxide, sulphur dioxide and carbon monoxide; nitrogen and hydrogen are other chief gases.



Kinds of Volcano:

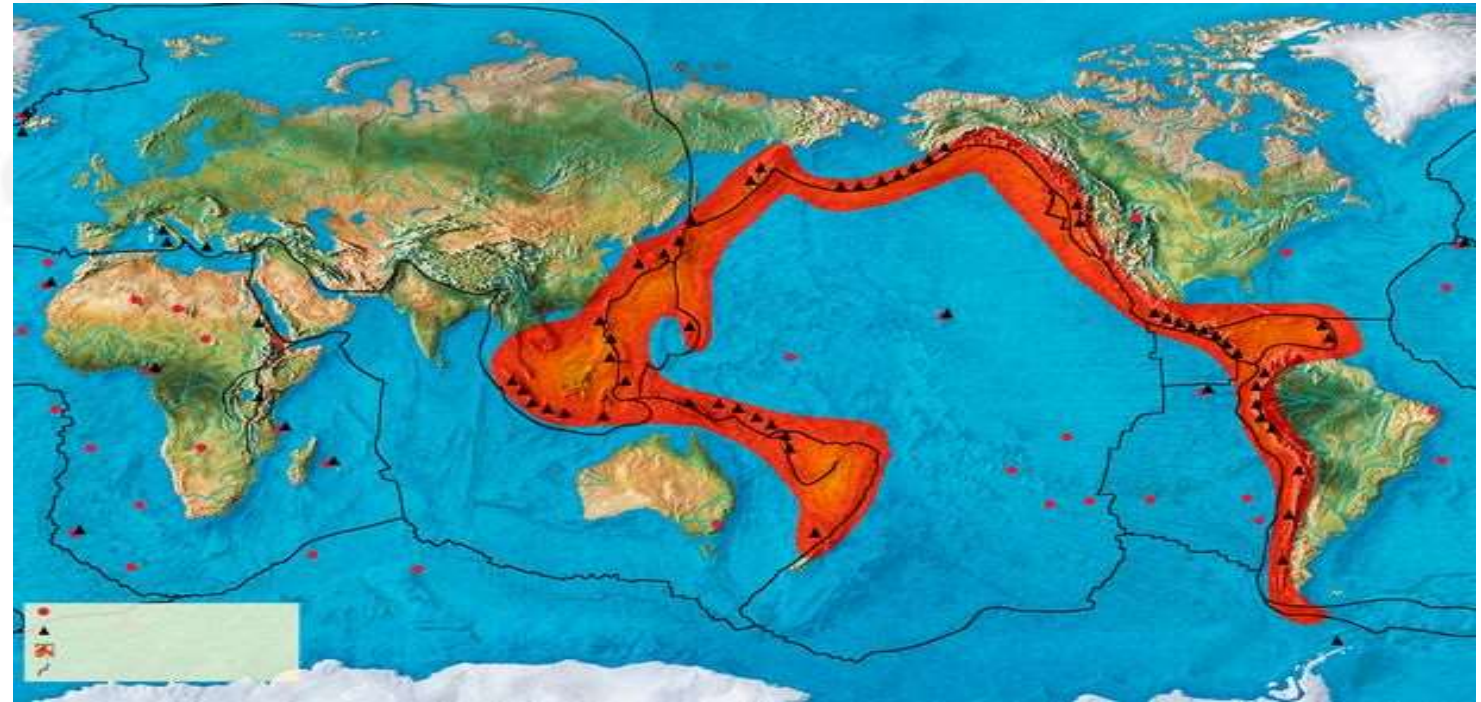
- Depending upon the time interval between two volcanic eruptions the volcanoes are divided in the following 3 kinds
- 1. **Active Volcano:** is one, from which a volcanic eruption can be erupted at any time. The eruption may take place after a few years or tens of years.
- 2. **Dormant Volcano:** is one, which erupts with a period of rest that could be a few years, or several years.
- 3. **Extinct Volcano:** is one, where the activity of the volcano seems to have ceased altogether.

Effects of Volcano:

- Whenever the volcanic eruption takes place the places around or the area under influence of volcano will be burnt and inflamed, leading to mass destruction of life and property.
- Flooding of volcanic mud and deposition of ash around the volcano, which causes dust pollution, contamination of lakes or water bodies, suffocation and introduction of harmful gases in the atmosphere leading to death of people and loss of property.
- Some times earthquakes are triggered due to volcanic eruptions and that can devastate the land surface and human settlements.



- A great majority of major and minor volcanoes of the world appear to be concentrated along two main belts. The Circum Pacific Belt and Alpine - Himalayan Belt. The first belt is well defined and covers many parts of America, Japan, East Indies, and New Zealand etc., the belts are not continuous.



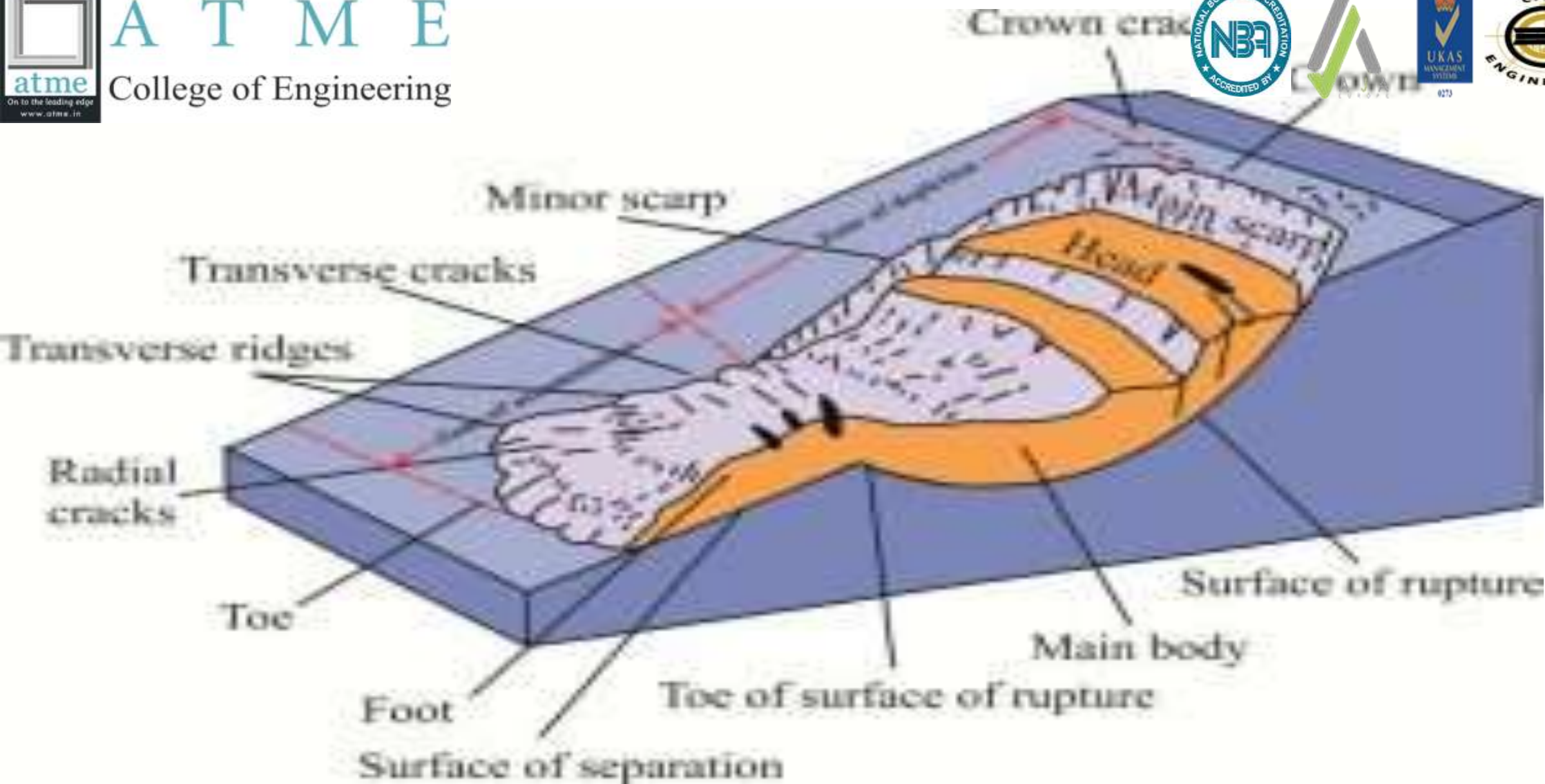
Landslides

- Landslides are mass movements of rock, debris, or earth down a slope when the shear stress exceeds the shear strength of the material. The movement is in response to gravity and water. During rainy season landslides are common along the hill slopes.



PARTS OF A TYPICAL SLIDE:

- **Crown:** The upper portion still in place from which solid rock and soil materials are torn away from rest of the slope.
- **2. Scarp:** The steep walls of the undisturbed materials below crown around the periphery of the slide material.
- **3. Head:** The upper part of the slide material.
- **4. Flanks:** Sides of a slide (Left flank, Right flank)
- **5. Transverse ridges:** Terrace or step like features.
- **6. Foot:** The line of intersection of the lower part of the slip plane & the original ground surface.
- **7. Length:** Horizontal distance from crown to toe.
- **8. Width:** Horizontal distance from flank to flank.
- **9. Depth:** Thickness of the slide mass between crown to foot.
- **10. Height:** Vertical distance (Crown to toe).

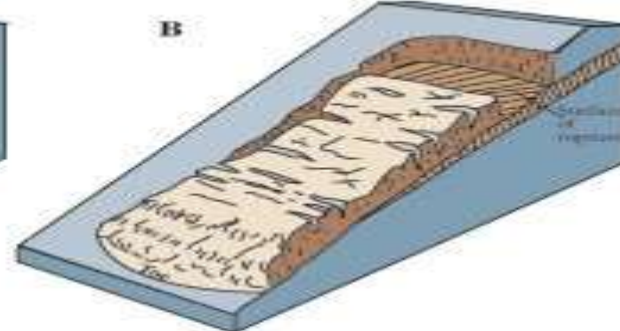


Classification of Landslides :

- All movement of land masses are referred as landslides, but differ in many respects, therefore all types of landslides are categorized as Earth Movements. These are classified as: Earth flow (Flowage), Sliding and Subsidence.
- **Solifuction:** is a downward movement of wet soil along the slopes under the influence of gravity. It takes place in regions of cold climate where ground freezes to a considerable depth.
- **2. Soil creep or soil slip** - slow downward movement of soil, or unconsolidated material like sand, gravel, and other loose materials.
- **Mud flow and earth flow:** these are rapid types of mass movements and usually follow old stream channels. Mudflows are produced in steep mountain areas where large amount of loose earth materials are available and where abundant water supply by heavy rain or melting of snow.



Rotational landslide



Translational landslide



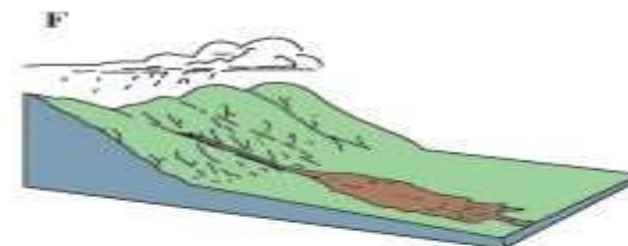
Block slide



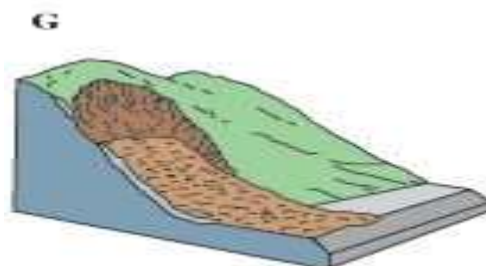
Rockfall



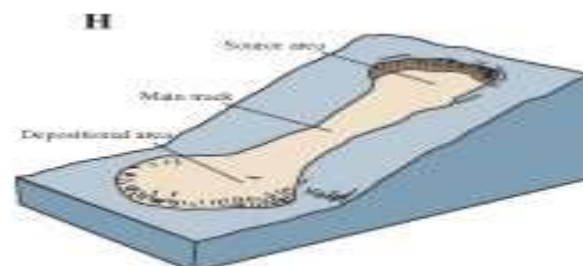
Topple



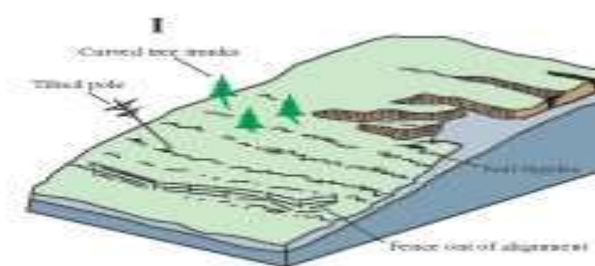
Debris flow



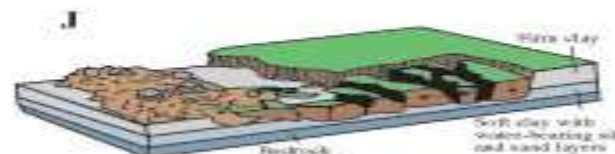
Debris avalanche



Earthflow



Creep



Lateral spread

- **CAUSES OF LANDSLIDES:** Many factors are known to cooperate in causing a mass of material to flow/ fail/ fall. Some of them play a direct role and others are indirectly responsible for the instability of landmass. They are:
- **Internal causes-** These include such causes, which tend to reduce the shearing strength of soil or rock mass by virtue of which it had remained stable at a given position on the ground.
- **1. Influence of slope-** Provides favourable condition for landslides; steeper slope are prone to slippage of land.

- **.Ground water or associated water-** Main factor responsible for slippage. Suppose the hard or massive rocks are underlain by softer rocks (shale or clay bed)
- • When rain water percolates through some fractures or joints the clayey beds becomes very plastic and acts as slippery base, which enhance the chances of loose overburden to slip downward.
- • Water is the most powerful solvent, which not only causes decomposition of minerals but also leaches out the soluble matter of the rock and reduces the strength.
- **3. Lithology-** rock which are rich in clay (montmorillonite, bentonite), mica, calcite, gypsum etc are prone to landslide because these minerals are prone to weathering.
- **4. Geological structures-** Occurrence of inclined bedding planes, joints, fault or shear zone are the planes of weakness, which create conditions of instability.
- **5. Human Influence-** undercutting along the hill slopes for laying roads or rail tracks can result into instability.

- **External causes –**

- ☐ Excessive load on the slope, may be due to heavy structure, heavy traffic and even snow fall. ☐ Removal of material at the toe or foot of the slope.
- ☐ Cuttings made on the slopes for road or rail, etc
- ☐ Earthquakes.

- **EFFECTS**

- ☐ **Landslides causes – damage to property**, this brings loss to the economy of the country and also needs rehabilitation.
- ☐ **Damage to infra structure.**
 - o Destruction to buildings.
 - o Destruction to villages or cities along hill slopes.
 - o Damage to roads.
- ☐ **Loss of life** - many lives lost upon the occurrences of landslides.
- ☐ There will be change in the **surface landscape**

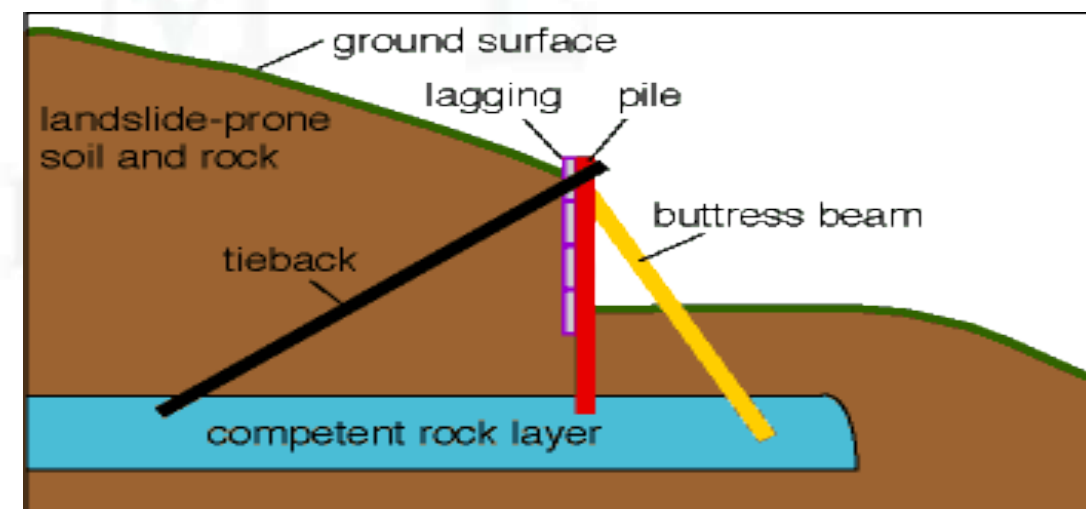


Remedial steps for landslides

- **1. Modification of Slope Geometry:** In order to improve the stability of the unstable or potentially unstable slopes, the profile of the slope is sometimes changed by excavation or by filling at the toe of the slope.
- **2. Drainage Control:** The presence of water in joints or in soil slope has a fundamental influence on the slope stability.
- **3. Internal Slope Reinforcement Systems:** The aim of rock slope stabilization with structural elements is to help the rock mass to support itself by applying external structures which are not part of the rock mass but support it externally.
- **4. Retaining Walls:** Construction of wall along the problematic slopes area

OTHER PREVENTIVE MEASURES:

- [?] Excessive loads from hill slopes must be reduced.
- [?] If shearing stress is too high, materials from the head of the slope may be removed.
- [?] Dumping extra material at toe of the slope provides more stability.
- [?] Slopes, if very steep, may be flattened.
- [?] Restriction on use of explosive should be imposed along hill slopes.
- [?] Landslides may be checked by providing retaining walls.
- [?] Seepage of water must be checked by providing proper drainage



- [?] Loose soil along slopes may be stabilized by turfing.
- [?] Weak zones like joints, fissures etc are stabilized by grouting along hill slopes.



~~THANK YOU~~

ATME
College of Engineering