EARTHQUAKE TSUNAMI AND VOLCANIC ACTIVITY AND ASSOCIATED LANDFORMS

Contents:

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Earthquakes

An earthquake in simple words is shaking of the earth. It is caused due to release of energy, which generates waves that travel in all directions.

The release of energy occurs along a fault. A fault is a sharp break in the crustal rocks. Rocks along a fault tend to move in opposite directions. As the overlying rock strata press them, the friction locks them together. However, their tendency to move apart at some point of time overcomes the friction. As a result, the blocks get deformed and eventually, they slide past one another abruptly. This causes dissipation of energy, and the energy waves travel in all directions.

The point where the energy is released is called the **focus** of an earthquake, alternatively, it is called the **hypocentre**. The energy waves travelling in different directions reach the surface. The point on the surface, nearest to the focus, is called **epicentre**. It is the first one to experience the waves. It is a point directly above the focus.

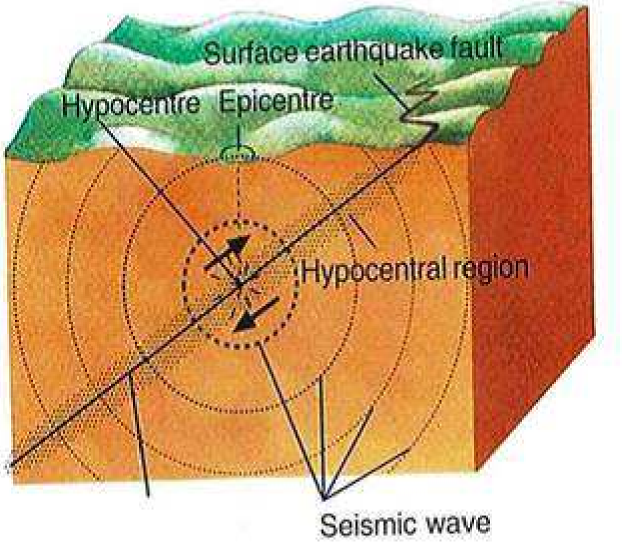

Figure 1: Hypocentre and Epicentre

Types of Earthquakes

1. **Tectonic Earthquakes**: These are generated due to sliding of rocks along a fault plane. This movement causes imbalance in the crustal rocks which results in earthquakes of varying magnitude, depending upon the nature of dislocation in the rock strata.
2. **Volcanic Earthquakes:** Volcanic activity is considered to be one of the main causes of earthquakes. In fact, volcanic activity and seismic events are so intimately related to each other that they become cause and effect for each other. Each volcanic eruption is followed by an earthquake and many of the severe earthquakes can cause volcanic eruptions.
   The explosive violent gases during the process of volcanic activity try to escape upward and hence they push the crustal surface from below with great force. This leads to severe tremors of high magnitude, which depend upon the intensity of volcanic eruptions.
3. **Collapse Earthquakes:** In areas of intense mining activity, sometimes the roofs of underground mines collapse causing minor tremors.

4. **Explosion Earthquakes:** Ground shaking may also occur due to the explosion of chemical or nuclear devices.
5. The earthquakes that occur in the areas of large reservoirs are referred to as **reservoir induced earthquakes**.
   Above may also be referred as various causes of earthquakes with one and two being the **natural causes** of earthquakes while three, four and five represent **anthropogenic** or **man-made** causes of earthquakes.

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Seismic waves

The waves generated by an earthquake are called the 'seismic waves' or 'earthquake waves'. These are recorded by an instrument called the **seismograph** or the **seismometer**. For further understanding of earthquake waves, refer to the portion of the notes on 'Interior of Earth'.

Depth of Earthquakes

Earthquake focus depth is an important factor in shaping the characteristics of the waves and the damage they inflict. The focal depth can be **deep** (from 300 to 700 km), **intermediate** (60 to 300 km) or **shallow** (less than 60 km). Deep focus earthquakes are rarely destructive because the wave amplitude is greatly attenuated by the time it reaches the surface. Shallow focus earthquakes are more common and are extremely damaging because of their close proximity to the surface

Measurement of Earthquakes

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

Magnitude Scale

Magnitude is the amount of energy released and is based on the direct measurement of the size of seismic waves. The magnitude scale is known as the **Richter Scale**.

The **Richter magnitude scale** was developed in 1935 by Charles F. Richter as a mathematical device to compare the size of earthquakes. The magnitude of an earthquake is determined from the *logarithm of the amplitude* of waves recorded by seismographs. Because of the logarithmic basis of the scale, each whole number increase in magnitude represents a *ten fold increase* in measured amplitude; as an estimate of energy, each whole number step in the magnitude scale corresponds to the release of about 31 times more energy than the amount associated with the preceding whole number value.

Intensity Scale

Intensity of an earthquake is measured in terms of its effects on human life. The intensity of an earthquake at a specific location depends on a number of factors. Some of them are:

- the total amount of energy released,
- the distance from the epicentre,
- the types of rocks and the degree of consolidation.

The **Mercalli intensity scale** is a scale used for measuring the intensity of an earthquake. The scale quantifies the effects of an earthquake on the Earth's surface, humans, objects of nature, and man-made structures on a scale of **I** through **XII**, with I denoting 'not felt', and XII 'total destruction'. Data is gathered from individuals who have experienced the quake, and an intensity value will be given to their location.

Characteristic	Mercalli Scale	Richter Scale
Measures	The effects caused by earthquake	The energy released by the earthquake
Measuring Tool	Observation	Seismograph
Calculation	Quantified from observation of effect on earth's surface, human, objects and man-made structures	Base-10 logarithmic scale obtained by calculating logarithm of the amplitude of waves.
Scale	I (not felt) to XII (total destruction)	From 2.0 to 10.0+ (never recorded). A 3.0 earthquake is 10 times stronger than a 2.0 earthquake.
Consistency	Varies depending on distance from epicentre.	Varies at different distances from the epicentre, but one value is given for the earthquake as a whole.

Table 1: Comparison between Richter and Mercalli Scale

Classification of Earthquakes

Category	Magnitude on Richter Scale
Slight	Upto 4.9
Moderate	5.0 to 6.9
Great	7.0 to 7.9
Very Great	8.0 and more

Table 2: classification of earthquakes based on magnitude

Distribution of Earthquakes

Most earthquakes in the world are associated with the following:

- the zones of young fold mountains,
- the zones of faulting and fracturing,
- the zones representing the junctions of continental and oceanic margins,
- the zones of active volcanoes, and
- along the different plate boundaries.

Seismic Belts of the world

The main seismic belts are as under:

1. **Circum-Pacific Belt:** The Belt includes the coastal margins of North America, South America and East Asia. These are as represent the eastern and western margins of the

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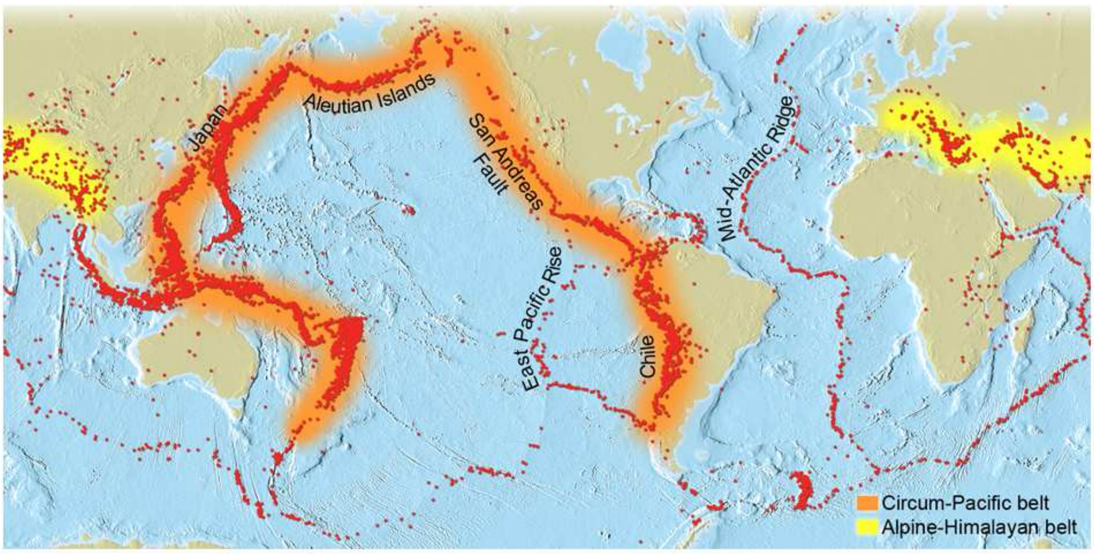
Pacific Ocean respectively, and account for about 65 per cent of the total earthquakes of the world.

The **western marginal zones** are represented by the Rockies and the Andes mountain chains. These are also the zones of convergent plate boundaries where the Pacific oceanic plate is subducted below the American plates.

The **eastern marginal zones** are represented by the island arcs of Kamchatka, Sakhalin, Japan and Philippines. The earthquakes are caused due to collision of the Pacific and the Asiatic plates and the consequent volcanic activity. Japan records about 1500 seismic shocks every year.

2. **Mid-Continental Belt:** The Mid-Continental Belt includes the Alpine mountains and their off shoots in Europe, Mediterranean Sea, northern Africa, eastern Africa and the Himalayas.

   The Mid-Continental Belt extends through Sulaiman and Kirthar zones in the west, the Himalayas in the north and Myanmar in the east. This belt represents the weaker zone of Fold Mountains. About 21 per cent of the total seismic events are recorded in this belt.
3. **Mid-Atlantic Ridge Belt:** The Mid-Atlantic Ridge Belt includes the Mid-Atlantic ridge and several islands near the ridge. It records moderate earthquakes which are caused due to the moving of plates in the opposite directions. Thus the seafloor spreading and the fissure type of volcanic eruptions cause earthquakes of moderate intensity in this region.



Distribution of nearly 15,000 earthquakes with magnitudes equal to or greater than 5 for a 10-year period.

Figure 2: Distribution of Earthquake belts

Seismic Zones of India

The Indian sub-continent is highly prone to multiple natural disasters including earthquakes, which is one of the most destructive natural hazards with the potentiality of inflicting huge loss to lives and property. Earthquakes pose a real threat to India with 59% of its geographical area vulnerable to seismic disturbance of varying intensities including the capital city of the country.

The varying geology at different locations in the country implies that the likelihood of damaging earthquakes taking place at different locations is different. Thus, a seismic zone map is required so that buildings and other structures located in different regions can be designed to withstand different level of ground shaking. The current zone map divides India into four zones – II, III, IV and V.

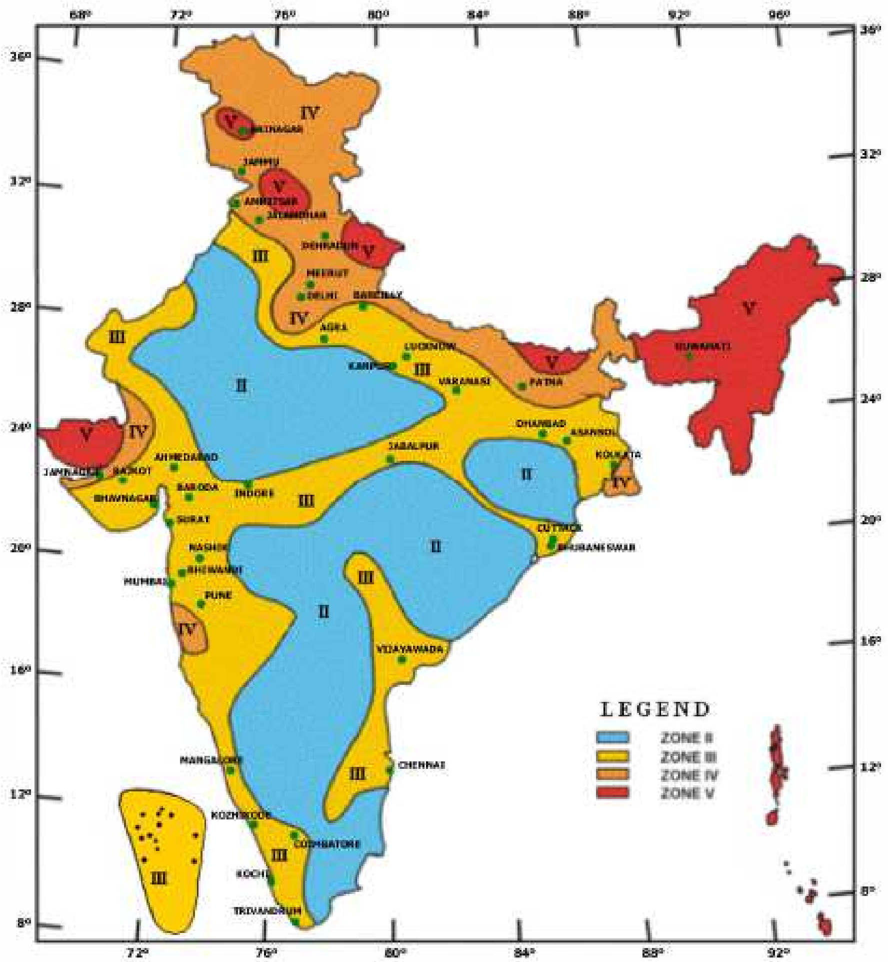


Figure 3: Seismic Zones of India

The following table gives the distribution of various regions of the country into various seismic zones:

Zone	Damage risk	Region
Zone V	Very high damage risk zone	The entire North-east, including the seven sister states, the Kutch district, parts of Himachal and Jammu & Kashmir, and the Andaman and Nicobar islands.
Zone IV	High damage risk zone	Parts of the Northern belt starting from Jammu and Kashmir to Himachal Pradesh. Also including Delhi and parts of Haryana. The Koyna region of Maharashtra is also in this zone.
Zone III	Moderate damage risk zone	A large part of the country stretching from the North including some parts of Rajasthan to the South through the Konkan coast, and also the Eastern parts of the country.
Zone II	Low damage risk zone	These two zones are contiguous, covering parts of Karnataka, Andhra Pradesh, Orissa, Madhya Pradesh, and Rajasthan, known as low risk earthquake zones.

Table 4: Region falling in various zones of the country

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Effects of Earthquakes

The direct and indirect effects of an earthquake includes:

1. **Deformed Ground Surface:** The earthquake tremors and the resultant vibrations, result in the deformation of the ground surface, due to the rise and subsidence of the ground surface and faulting activity. The alluvium filled areas of the flood plains may get fractured at several places.
2. **Damage to man-made structures:** Man-made structures such as buildings, roads, rails, factories, dams, bridges, etc., get severely damaged.
3. **Damage to towns and cities:** The towns and cities are the worst affected due to a high density of buildings and population. Under the impact of tremors, large buildings collapse and men and women get buried under the debris. Ground water pipes are damaged and thus water supply is totally disrupted.
4. **Loss of human and animal life:** The destructive power of an earthquake depends upon the loss it can cause in terms of loss of life arid property. The Bhuj earthquake of India in 2001 (8.1 on the Richter Scale) caused over one lakh human casualties.
5. **Devastating fires:** The strong vibrations caused by an earthquake can cause fire in houses, mines and factories due to the bursting of gas cylinders, contact with live electric wires, churning of blast furnaces, displacement of other electric and fire related appliances.
6. **Landslides:** The tremors in hilly and mountainous areas can cause instability of unconsolidated rock materials. This ultimately leads to landslides, which damage settlements and transport systems.
7. **Flash floods:** Very strong seismic events result in the collapse of dams and cause severe flash floods. Floods are also caused when the debris produced by tremors blocks the flow of water in the rivers. Sometimes the main course of the river is changed due to the blockage.
8. **Tsunamis:** When the seismic waves travel through sea water, high sea waves are generated, which can cause great loss to life and property, especially in the coastal areas.

Tsunami

Tsunami is a Japanese word which means 'harbour wave'. It is a series of traveling ocean waves of extremely long length generated by disturbances associated primarily with earthquakes occurring below or near the ocean floor. Underwater volcanic eruptions and landslides can also generate tsunamis. Tsunamis are a threat to life and property to anyone living near the ocean. Large tsunamis have been known to rise over 100 feet, while tsunamis 10 to 20 feet high can be very destructive and cause many deaths and injuries.

Causes

Tsunamis generally are caused by earthquakes. Not all earthquakes generate tsunamis. To generate tsunamis, earthquakes must occur underneath or near the ocean, be large and create movements in the sea floor. All oceanic regions of the world can experience tsunamis, but in the Pacific Ocean there is a much more frequent occurrence of large, destructive tsunamis because of the many large earthquakes along the margins of the Pacific Ocean.

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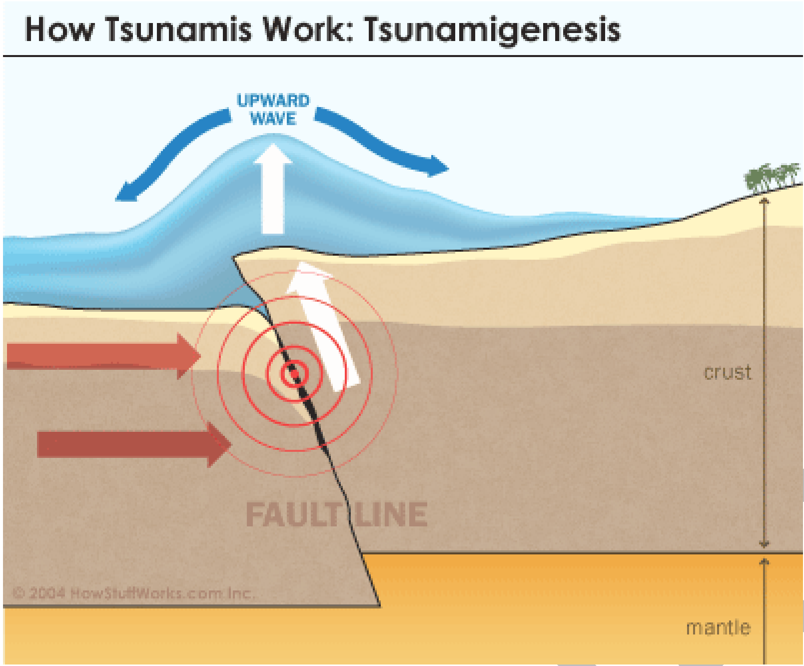

Figure 4: Generation of Tsunami

Other less common causes of earthquakes are **submarine landslides**, **submarine volcanic eruptions** and very rarely a **large meteorite impact in the ocean**.

Propagation

In the open ocean a tsunami is less than a few feet high at the surface, but its wave height increases rapidly in shallow water. Tsunamis wave energy extends from the surface to the bottom in the deepest waters. As the tsunami attacks the coastline, the wave energy is compressed into a much shorter distance creating destructive, life-threatening waves.

Where the ocean is over 20,000 feet deep, unnoticed tsunami waves can travel at the speed of a commercial jet plane, nearly 600 miles per hour. They can move from one side of the Pacific Ocean to the other in less than a day. This great speed makes it important to be aware of the tsunami as soon as it is generated. Scientists can predict when a tsunami will arrive since the speed of the waves varies with the square root of the water depth. Tsunamis travel much slower in shallower coastal waters where their wave heights begin to increase dramatically.

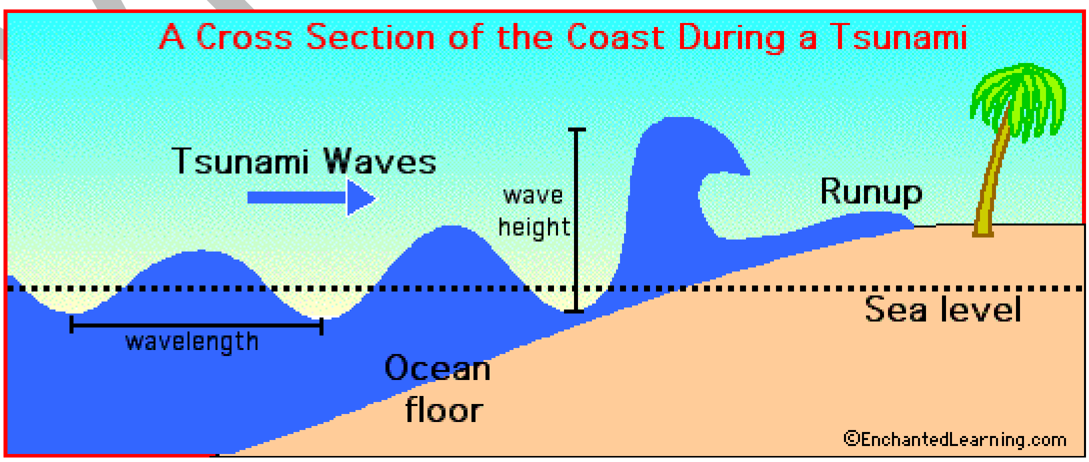

Figure 5: Rise in Tsunami amplitude near the coast

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Offshore and coastal features can determine the size and impact of tsunami waves. Reefs, bays, entrances to rivers, under sea features and the slop of the beach all help to modify the tsunami as it attacks the coastline. When the tsunami reaches the coast and moves inland, the water level can rise many feet. In extreme cases, water level has risen to more than 50 feet for tsunamis of distant origin and over 100 feet for tsunami waves generated near the earthquake's epicentre.

Consequences

The consequences vary from loss of livelihood for fishermen to unknown damages to coral reefs and flora and fauna. It may take years for the coral reefs to get back the balance and mangrove stands and coastal tree plantations get destroyed or severely affected.

With so much sea water coming inland, salination is another effect that not only makes the soil less fertile to support vegetation but also increases vulnerability to erosion, the impacts of climate change and food insecurity. For humans, on the other hand, fisheries, housing and infrastructure are the worst affected.

Early Warning and Mitigation

Major tsunami warning centres are:

1. **Pacific Tsunami Warning Center (PTWC):** The Tsunami Warning System (TWS) in the Pacific, comprised of 26 participating international Member States, has the functions of monitoring seismological and tidal stations throughout the Pacific Basin to evaluate potentially tsunami genic earthquakes and disseminating tsunami warning information. The Pacific Tsunami Warning Center is the operational center of the Pacific TWS. Located near Honolulu, Hawaii, PTWC provides tsunami warning information to national authorities in the Pacific Basin.

2. **The Alaska Tsunami Warning Center (ATWC):** in Palmer, Alaska, serves as the regional Tsunami Warning Center for Alaska, British Columbia, Washington, Oregon, and California.
3. **Indian Tsunami Early Warning System (ITEWS):** The Indian Tsunami Early Warning System has the responsibility to provide tsunami advisories to Indian Mainland and the Island regions. Acting as one of the Regional Tsunami Advisory service Providers (RTSPs) for the Indian Ocean Region, ITEWS also provide tsunami advisories to the Indian Ocean Rim countries along with Australia and Indonesia.

In order to confirm whether the earthquake has actually triggered a tsunami, it is essential to measure the change in water level as near to the fault zone with high accuracy. There are two basic types of sea level gages: **coastal tide gages** and **open ocean buoys**.

Tide gages are generally located at the land-sea interface, usually in locations somewhat protected from the heavy seas that are occasionally created by storm systems. Tide gages that initially detect tsunami waves provide little advance warning at the actual location of the gage, but can provide coastal residents where the waves have not yet reached an indication that a tsunami does exist, its speed, and its approximate strength.

Open ocean tsunami buoy systems equipped with **bottom pressure sensors** are now a reliable technology that can provide advance warning to coastal areas that will be first impacted by a tsunami, before the waves reach them and near by tide gages. Open Ocean buoys often provide a better forecast of the tsunami strength than tide gages at distant locations.

Apart from technology, we can also use **natural barriers** to mitigate the effect of tsunamis. **Coral reefs** act as natural breakwaters, providing a physical barrier that reduces the force of a wave before it reaches the shore, while **mangrove forests** act as natural shock absorbers, also soaking up destructive wave energy and buffering against coastal erosion.

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Volcanoes

The word **volcano** is derived from the name of 'Vulcano', a volcanic island in the *Aeolian Islands* of Italy whose name in turn originates from 'Vulcan', the name of a god of fire in *Roman mythology*.

Volcano is a **vent** or an opening through which heated materials consisting of *water*, *gases*, *liquid lava* and *rock fragments* are erupted from the highly heated interior to the surface of the Earth. The layer below the solid crust of earth is **mantle**. It has higher density than that of the crust. The mantle contains a weaker zone called **asthenosphere**. It is from this that the molten rock materials find their way to the surface. The material in the upper mantle portion is called **magma**. Once it starts moving towards the crust or it reaches the surface, it is referred to as **lava**.

'*Volcanology'* or '*vulcanology'* is the term given to the study of volcanoes, and the scientists who study them are called the '*volcanologists*' or '*vulcanologists*'.

Vulcanicity

Vulcanicity includes all those processes in which molten rock material or magma rises to the crust to solidify as crystalline or semi-crystalline rocks. Some scientists use '*vulcanism*' as a synonym for vulcanicity.

Vulcanicity has two components; one of them operates below the crustal surface and the other above the crust, i.e. the endogenetic mechanism and the exogenous mechanism. The **endogenetic mechanism** includes the creation of hot and liquid magma and gases in the mantle and the crust, their expansion and upward ascent, their intrusion and cooling and solidification in various forms below the crustal surface. The **exogenous mechanism** includes the process of the appearance of lava, volcanic dust and ashes, fragmental materials, mud, smoke, etc., in different forms on the earth's surface.

Causes of Vulcanism

The mechanism of vulcanism and the volcanic activity are associated with several processes, such as:

1. A gradual increase of temperature with increasing depth at the rate of 1 degree Celsius for every 32 m.
2. Magma is formed due to the lowering of melting point, which in turn is caused by the reduction in pressure of the overlying material.
3. Gases and vapour are formed due to heating of water, which reaches underground through percolation.
4. The ascent of magma forced by vast volume of gases and water vapour.
5. The occurrence of volcanic eruption.

Components of a Volcano

The volcanoes of explosive type have a **volcanic cone**, which is formed when the erupted material accumulates around the vent. The **vent** is an opening of circular or nearly circular shape at the centre of the cone. The vent is connected to the interior of the earth by a **narrow pipe**. The volcanic materials erupt through this pipe. A funnel-shaped hollow at the top of the cone is called the **crater**.

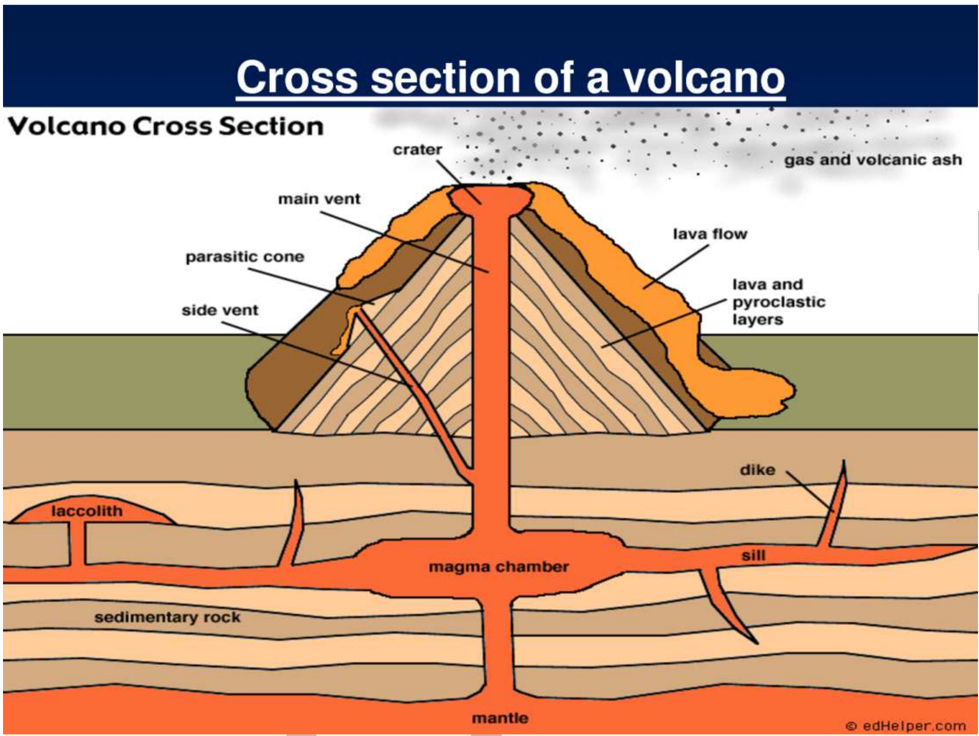

Figure 6: Components of a volcano

Types of lavas

There are two main types of lavas:

1. **Basic Lavas:** These are the hottest lavas and are *highly fluid*. They are dark coloured like *basalt*, rich in iron and magnesium but poor in silica. They flow quietly and are not very explosive. They affect extensive areas, spreading out as thin sheets over great distances before they solidify. The resultant volcano is gently sloping with a wide diameter and forms a flattened *shield* or *dome*.

2. **Acid Lavas:** These lavas are highly viscous with a high melting point. They are *light coloured*, of low density and have a high percentage of silica. They flow *slowly* and seldom travel far before solidifying. The resultant volcano is therefore *steep-sided*. The rapid cooling of lava in the vent obstructs the flow of the outpouring lava, resulting in loud explosions throwing out many *volcanic bombs* or *pyroclasts*.

Note: Pyroclasts are any volcanic fragment that was hurled through the air by volcanic activity.

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Types of volcanoes

There is a wide variation in the mode of volcanic eruption and their periodicity. Accordingly the volcanoes can be classified on the basis of the mode of eruption and their periodicity of eruption.

Classification on the basis of mode of eruption: The volcanoes are classified into two groups on the basis of their *mode* of eruption:

1. **Violent or Explosive type:** The eruption of violent or explosive type is so rapid that huge quantities of volcanic materials are ejected thousands of metres in the sky. On falling, these materials accumulate around the volcanic vent and form volcanic cones. Such volcanoes are very destructive. They are generally associated with acidic lavas.

2. **Effusive or Fissure type:** The eruption of the fissure type of volcanoes-occurs along a long fracture, fault or fissure. Magma ejects slowly and the resultant lava spreads on the surface. The speed of the lava flow depends on the nature and volume of magma, slope of the ground and the temperature conditions.

Classification on the basis of periodicity of eruption: The volcanoes are divided into three types on the basis of the periodicity of their eruption:

1. **Active Volcanoes:** Volcanoes are said to be active when they frequently erupt or at least when they have erupted within recent time. Etna and Stromboli are typical examples.
2. **Dormant Volcanoes:** Volcanoes that have been known to erupt and show signs of possible eruption in future are described as dormant. Mt. Vesuvius is the best example.
3. **Extinct Volcanoes:** Volcanoes that have not erupted at all in historic times but retain the features of volcanoes are termed extinct. Ship rock in Netherlands is one such example.

All volcanoes pass through active, dormant and extinct stages but it is impossible to be thoroughly sure when a volcano has become extinct.

Volcanic Landforms

Various landforms are created due to the cooling and solidification of magma (below the Earth's surface) and lava (on the Earth's surface). Some relief features are formed due to the accumulation of volcanic materials. The volcanic landforms are grouped into two broad categories: **Extrusive** landforms and **Intrusive** landforms.

Extrusive Landforms

Extrusive landforms are determined by the nature and composition of the lava. Major extrusive landforms are as under:

1. **Cinder or ash cones** are formed due to the accumulation of loose particles around the vent. Its size increases due to the continuous accumulation of volcanic material minus lava. The larger particles are arranged near the crater and the finer particles are deposited at the outer margins of the cone. The lava flows are so viscous that they solidify after a short distance.
2. **Composite cones** are the highest and are formed by the accumulation of various layers of volcanic material. They have alternate layers of lava and fragmented

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material, wherein lava acts as the cementing material. These are mainly associated with cooler and more viscous lava and the volcanoes associated with them are called **composite volcanoes**.

3. **Shield Volcanoes** are built almost entirely of fluid lava flows**.** They are named for their large size and low profile, resembling a warrior's shield lying on the ground. Barring the basalt flows, the shield volcanoes are the largest of all the volcanoes on the earth. These volcanoes are mostly made up of basalt, a type of lava that is very fluid when erupted. For this reason, these volcanoes are not steep.
4. **Craters** are depressions formed at the mouth of the volcanic vent, which is usually funnel-shaped. Some volcanoes may have greatly enlarged depressions called **calderas**. These are the result of violent eruptions accompanied by the subsidence of much of the volcano into the magma beneath. Water may collect in the crater or the caldera forming crater or caldera lakes.
5. **Flood Basalt Provinces** are formed when volcanoes outpour highly fluid lava that flows for long distances. Some parts of the world are covered by thousands of sq. km of thick basalt lava flows. There can be a series of flows with some flows attaining thickness of more than 50 m. Individual flows may extend for hundreds of km. The *Deccan Traps* from India, presently covering most of the Maharashtra plateau, are a much larger flood basalt province.

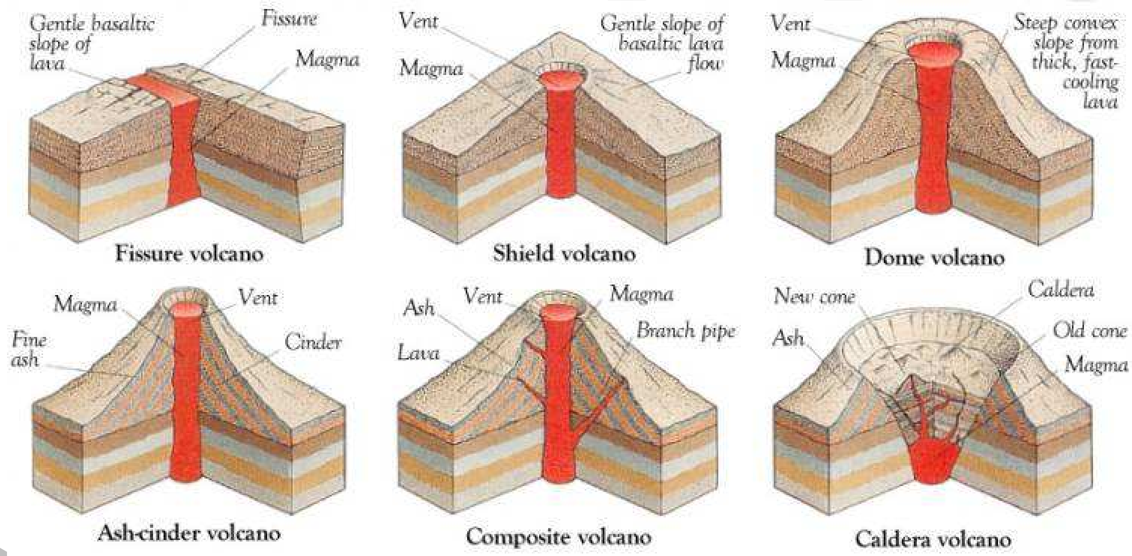

Figure 7: Volcanoes based on extrusive landforms

Intrusive Landforms

The lava that cools within the crustal portion assumes different forms called intrusive forms. Some of these forms are:

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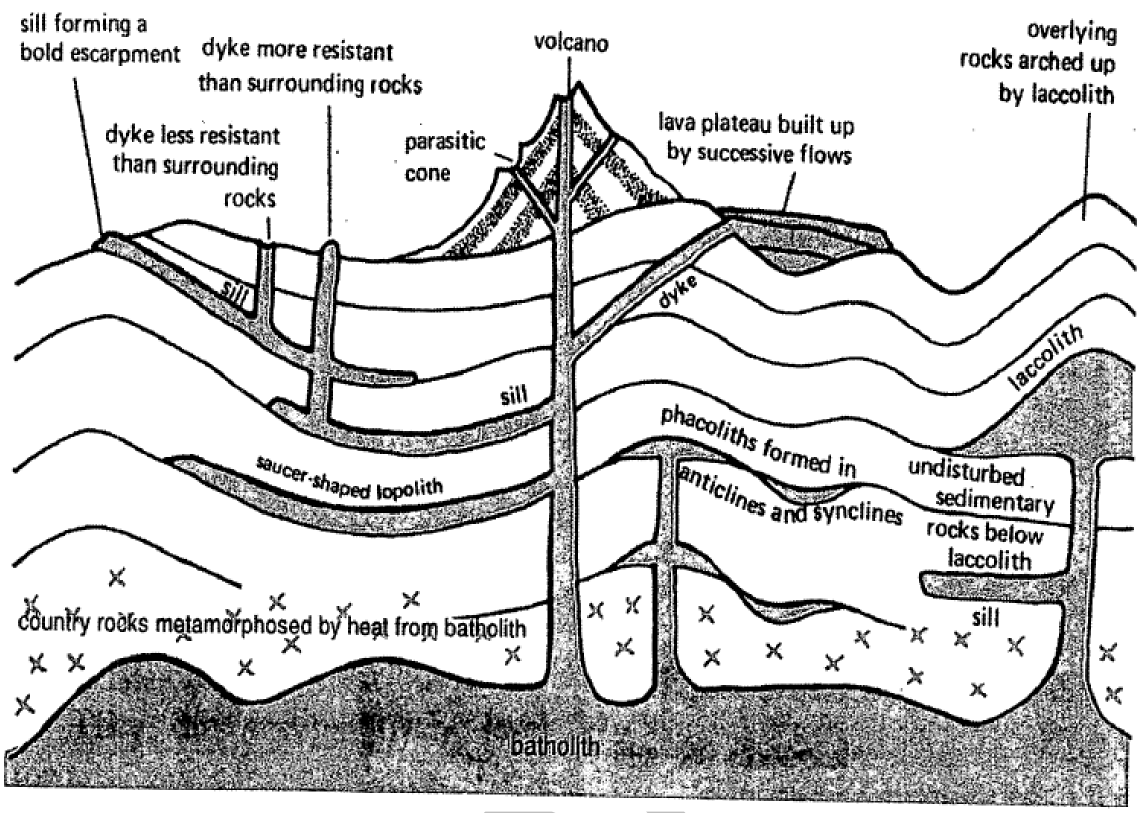

Figure 8: Various intrusive landforms formed in volcanic regions

1. **Batholiths** are long, irregular, undulating and dome-shaped features. They are a large body of magmatic material that cools in the deeper depth of the crust and develops in the form of large domes. They appear on the surface only after the denudational processes remove the overlying materials. They cover large areas, and at times, assume depth that may be several km. These are granitic bodies. Batholiths are the cooled portion of magma chambers.
2. **Laccoliths** are formed due to the intrusion of magma along the bedding planes of horizontal sedimentary rocks. They are usually mushroom or dome shaped.
3. **Phacoliths** are formed due to the intrusion of acidic magma along the anticlines and synclines in the region of fold mountains.
4. **Lapoliths** are formed when magma solidifies in shallow basins into a saucer shape.
5. **Sills** and **Sheets** are intrusive igneous rocks usually parallel to the bedding planes of sedimentary rocks. Depending on the thickness of deposits, thinner ones are called **sheets** while thick horizontal deposits are called **sills.**
6. **Dykes** are wall-like formation of solidified magma. These are vertical to the bed of sedimentary rocks. The thickness ranges from a few centimetres to several hundred metres, but the length can be several kilometres.

Distribution of Volcanoes

The volcanoes are mostly associated with the weaker zones of the Earth's crust which are also zones of seismic activities like the earthquakes. The weaker zones are mostly found in the areas of fold mountains. They are also associated with the meeting zones of oceans and continents, or with the mountain building activity.

Most of the world's active volcanoes are associated with the plate boundaries. About 15 per cent of the volcanoes are associated with the divergent plate boundaries and about 80 per cent

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with the convergent plate boundaries. Some volcanoes are also found in the intra-plate regions.

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The main volcanic belts are as under:

1. **Circum-Pacific Belt:** It includes the volcanoes of the eastern and western coastal areas of the Pacific Ocean. This belt is also known as the **Ring of Fire** of the Pacific Ocean.

   It begins from Erebus mountains of Antarctica and runs northwards through Andes of South America and Rockies of North America to reach Alaska. From there, it turns eastwards along the coast of Asia to include the volcanoes of Sakhalin and Kamchatka, Japan and Philippines respectively. This belt finally merges with the Mid-continental Belt in Indonesia.

   Most of the high volcanic cones and volcanic mountains are found in the Circum-Pacific Belt. *Cotopaxi* in Andes (5896 m) is the highest volcanic mountain in the world. The other famous volcanoes are *Fujiyama* (Japan), *Shasta*, *Rainier*, *Mt St Helena* (USA).

2. **Mid-Continental Belt:** It includes the volcanoes of the Alpine mountains and the Mediterranean Sea. The volcanic eruptions are caused due to the convergence and collision of the Eurasian Plates and the African and Indian Plates. Some of the famous volcanoes of the Mediterranean Sea such as the *Stromboli*, *Vesuvius*, *Etna*, etc., are in this belt. This belt is not continuous and has several volcanic free zones such as the Alps and the Himalayas. The important volcanoes in the fault zone of eastern Africa are *Kilimanjaro*, *Meru*, *Elgon*, *Rungwe*, etc.

3. **Mid-Atlantic Belt:** It includes the volcanoes along the mid-Atlantic ridge which is the divergent plate zone. They are mainly of the fissure eruption type. Iceland, is the most active volcanic area.

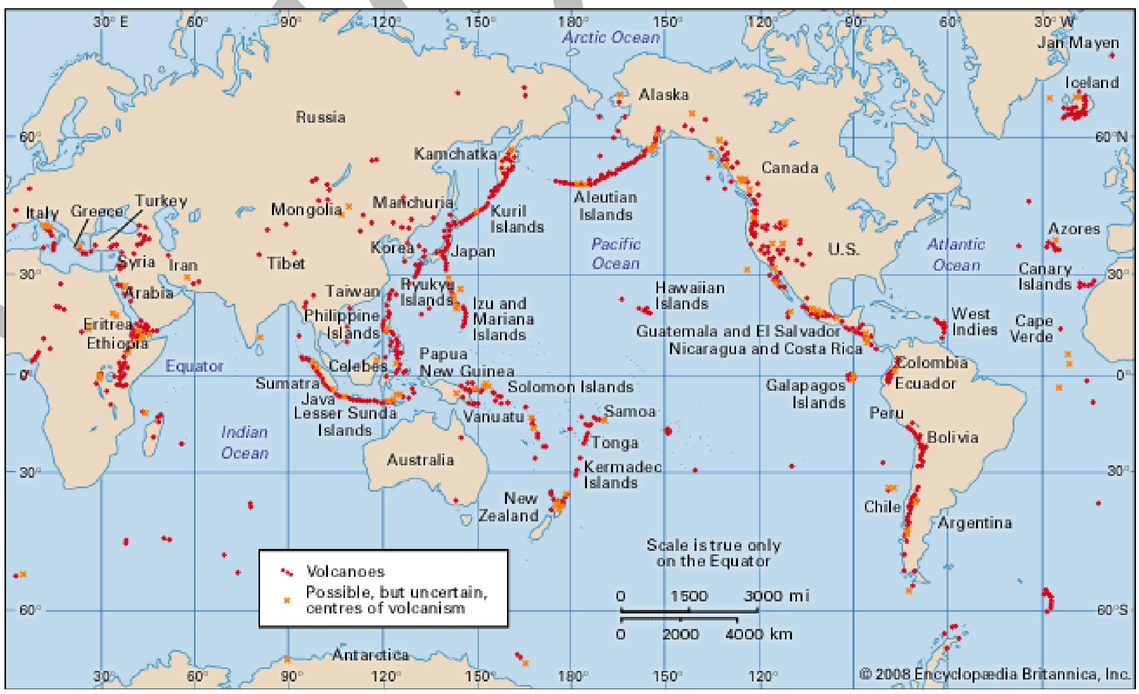

Figure 9: Distribution of volcanoes

Effects of volcanic eruptions

Volcanic eruption causes heavy damage to human life and property. Some of them are as under:

- Large volumes of hot lava moving at a fast speed can bury man-made buildings, kill people and animals, destroy agricultural farms and pastures, burn and destroy forests.
- The fall out of large quantities of fragmented materials, dust, ash, smoke, etc., creates health hazards due to poisonous gases emitted during eruption. It also causes **acid rain**.
- If the explosive eruption has occurred suddenly, the human beings get no time to escape to safer places. Heavy rains mixed with volcanic dust and ash cause enormous mud-flow on the steep slopes of the cones.
- Earthquakes caused due to explosive eruptions can generate destructive tsunamis, seismic waves, etc. These can cause loss of life and property in the affected coastal regions.
- The volcanic eruptions can change the heat balance of the Earth and the atmosphere, causing climatic changes.

But there are many **positive effects** also. Some of them are:

- Lava can give rise to fertile soils. Most of the precious stones are formed due to volcanic activity.
- Geysers and springs are tourist attraction and are also important from the medical point of view due to the chemicals dissolved in them.
- Some crater lakes are source of rivers and often offer scenic attraction for tourists.
- Most of the volcanic rocks when exposed on the surface are a storehouse of metals and minerals.

Geysers

Geysers are *fountains of hot water* and superheated steam that may spout up to a height of 150 feet from the earth beneath. The phenomena are associated with a thermal or volcanic region in which the water below is being heated beyond boiling point. The jet of water is usually emitted with an explosion, and is often triggered by gases seeping out of the heated rocks.

Almost all the world's geysers are confined to three major areas: Iceland, New Zealand and Yellowstone park of U.S.A.

Hot Springs

Hot springs or thermal springs are more common, and may be found in any part of the earth where water sinks deep enough beneath the surface to be heated by the interior forces. The water rises to the surface without any explosion. Such springs contain dissolved minerals which have medical value.

Student Notes:

Iceland has thousands of hot springs. Hot springs are common in many parts of India, especially in the hilly and mountainous parts. Some of them are in Manikaran (Kulu), Tattapani (Shimla), Jwalamukhi (Kangra), Rajgir (Patna), Sitakund (Munger) and in Yamunotri and Gangotri.

Student Notes:

Fumaroles

A fumarole is a vent in the Earth's surface which emits gases and water vapour. Sometimes the emission is continuous, but in majority of cases emission occurs after intervals. It is widely believed that gases and water vapour are generated due to cooling and contraction of magma after the eruption. Fumaroles are the last signs of the activeness of a volcano.