Contents

Chapter 3 – Interior of the Earth

The configuration of the surface of the earth is the result of constant **Endogenic** and **Exogenic** processes. Endogenic means Internal and exogenic means external.

Endogenic processes such as volcanic activities, folding of the crust, faulting due to plate tectonic activities, all these processes change the landscapes and collectively known as Endogenic process whereas Exogenic process such as weathering, Erosion, transportation, depositional, mass movement, denudation etc., all these act causes the outer surface of landscape.

Human life is largely influenced by the physiography of the region. Therefore, it is necessary that one gets acquainted with the forces that influence landscape development.

Sources of Information about the Interior

Most knowledge about the interior of the earth is largely based on estimates and inferences. Yet, a part of the information is obtained through direct observations and analysis of materials:

Direct Sources

1. **Rocks:** It is the strong evidence to know about the interior of the earth. The most easily available solid earth material is surface rock or the rocks we get from mining areas. As compared to surface rocks, mining rocks give us better knowledge about the interior of the earth because surface rocks undergo constant weathering through rain and water. That is why scientists have taken up a number of projects to penetrate deeper depths to explore the conditions in the crustal portions. There are some projects **like "Deep Ocean Drilling Project" and "Integrated Ocean Drilling Project** "to get the large volume of information and analysis the material for interior of the earth. **The deepest drill at Kola, in Arctic Ocean**, has so far reached a depth of **12 km.** It is the deepest drill till date.
2. **Volcanic eruption:** It is another source of obtaining direct information. As and when the molten material (magma) is thrown onto the surface of the earth, during volcanic eruption the sample of magma is tested by scientist to determine its components. However, it is difficult to ascertain the depth of the source of such magma.

Indirect Sources

1. Through **mining activity,** it has been observed that temperature and pressure increase as we go from the surface towards the interior in deeper depths and it is also known that the density of the material also increases with depth.
2. Another source of information are the **meteors** that at times reach the earth. However, it may be noted that the material that becomes available for analysis from meteors, is not from the interior of the earth. The material and the structure observed in the meteors are similar to that of the earth. They are solid bodies developed out of materials same as, or similar to, our planet. Hence, this becomes yet another source of information about the interior of the earth
3. The other indirect sources include **gravitation, magnetic field, and seismic activity.** The gravitation force (g) is not the same at different latitudes. It is greater near the poles and less at the equator it is because the Earth is not the perfect sphere. It has bulge at its centre so its distance from the centre at the equator being greater than that at the poles, the gravity keep changes as we move from one place to another but is maximum at the place where is nearer to the centre. This change in gravity reading is called **gravity anomaly.** The gravity values also differ according to the mass of material and material are unevenly distributed on Earth. **Magnetic surveys** also provide information about the distribution of magnetic materials in the crustal portion, and thus, provide information about the

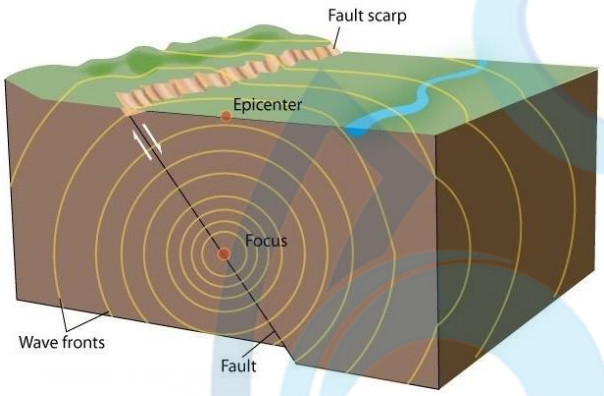
distribution of materials in this part. Seismic activity is one of the most important sources of information about the interior of the earth

Earthquake

An earthquake in simple words is shaking of the earth. It is a natural event. It is caused due to release of energy, which generates waves that travel in all directions. The study of seismic waves provides a complete picture of the layered interior

Why does the earth shake?

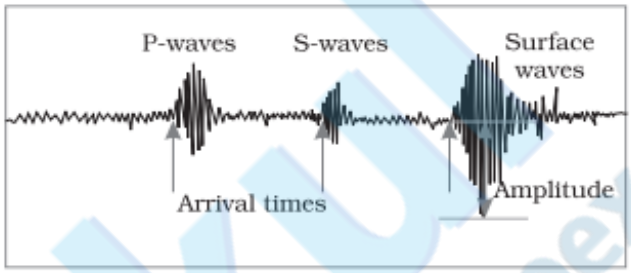
- The release of energy occurs along a fault. **A fault is a sharp break in the crustal rocks**. Rocks near a fault tend to move in opposite directions that creates friction but at some point of time their movements overcome friction, as a result they slide past one another. This causes a release of energy, and the energy waves travel in all directions.



- The point where the energy is released is called the **focus** of an earthquake, it is also 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.

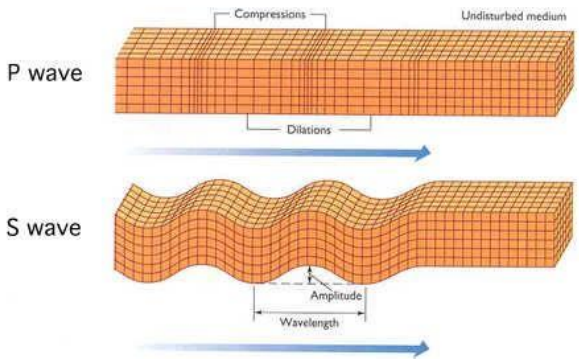
Earthquake Waves

- All natural earthquakes take place in the lithosphere. The lithosphere refers to the portion of depth up to 200 km from the surface of the earth.
- An instrument called **'seismograph'** records the waves reaching the surface. A curve of earthquake waves recorded on the seismograph and the curve shows three distinct sections each representing different types of wave patterns.



- Earthquake waves are basically of two types:
  1. **Body waves:** Body waves are generated due to the release of energy at the focus and move in all directions travelling through the body of the earth.
  2. **Surface waves:** When these body waves move towards the surface, they will come in contact with surface rocks and generate new set of waves called surface waves. These waves move along the surface.
- The velocity of waves changes as they travel through materials with different densities. The denser the material, the higher is the velocity. Their direction also changes as they reflect or refract when coming across materials with different densities. That is why, when the seismic waves reach to the surface of earth, there the material has lower density that slows down the intensity of the waves, leaving behind a fault.
- There are two types of body waves, they are:
  1. **P-waves** move faster and are the first to arrive at the surface. These are also called 'primary-waves'. The P-waves are similar to sound waves.
  2. **S-waves** arrive at the surface with some time lag. These are called secondary waves.

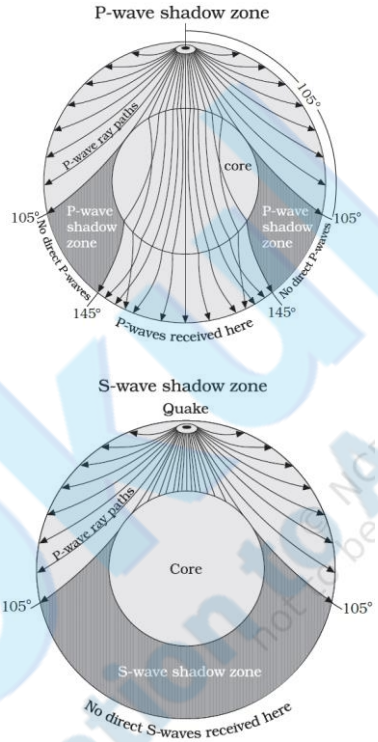
- The P waves is a pulse of energy that travels quickly through the earth through gaseous, liquid and solid materials, it forces the ground to move backward and forward as it get compressed and expanded whereas the S waves follows most slowly with swings and rolling motions that shakes ground back and forth perpendicular to the direction of waves



- After body waves, come the surface waves, the surface waves are the last to report on seismograph. These waves are more destructive. They cause displacement of rocks, and hence, the collapse of structures occurs.

Emergence of Shadow Zone

- Earthquake waves get recorded in seismographs located at far off locations. However, there exist some specific areas where the waves are not reported. Such a zone is called the **'shadow zone'.**
- It was observed that seismographs located at any distance within 105° from the epicentre, record the arrival of both P and S-waves. However, the seismographs located beyond 145° from epicentre, record the arrival of P-waves, but not that of S-waves.
- Thus, a zone between 105° and 145° from epicentre was identified as the shadow zone for both the types of waves. The entire zone beyond 105° does not receive S-waves. The shadow zone of S-wave is much larger than that of the P-waves.
- The shadow zone of P-waves appears as a band around the earth between 105° and 145° away from the epicentre.
- The shadow zone of S-waves is not only larger in extent but it is also a little over 40 per cent of the earth surface.



Types of Earthquakes

1. **Tectonic earthquakes**: It is most common, these are generated due to tectonic activity which is referred as to the breaking of the crust part of the earth surface, that is due to sliding of rocks along a fault plane.

2. **Volcanic earthquakes**: These are confined to areas of active volcanoes. When the Magma comes out of the volcano, this movement result in pressure changes in the rocks around where the magma experiences the stress and at some point the rock may break or move and when that happens the crust part of the Earth surface creates a fault.

3. **Collapse earthquakes**: This takes place in area of intense earth mining. Sometimes the roofs of underground mines collapse causing minor tremors.

4. **Explosion earthquakes**: Due to the explosion of chemical and nuclear devices, seismic waves are produced and these waves produces tremor which moves and break the rocks that creates an earthquake which is totally manually created

5. **Reservoir induced earthquakes:** The earthquakes that occur in the areas of large reservoirs. When reservoirs which is filled up with large quantity of water, it creates pressure and hits on the surface of reservoirs which exert pressure on the rocks and if there is crack in the crust that crack or fault increase in size due to pressure and tectonic activity happens.

Measuring Earthquakes

- A seismograph is used to detect the vibration caused by an earthquake, the strength or magnitude of an earthquake is measured using The Richter Scale. The magnitude is expressed in numbers, 0-10.
- The intensity of an Earthquake is determined by a Mercalli Scale which ranges from 0-12.

*Note: Richter scale determines **magnitude of an earthquake** on a scale of 0-10 whereas Mercalli Scale determines the **intensity of an earthquake** on a scale of 0-12.*

Effects of Earthquake

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

Effects affecting the landforms:

1. Ground Shaking
2. Differential ground settlement
3. Land and mud slides
4. Soil liquefaction
5. Ground lurching
6. Avalanches

Effects causing immediate concern to the life and properties of people in the region:

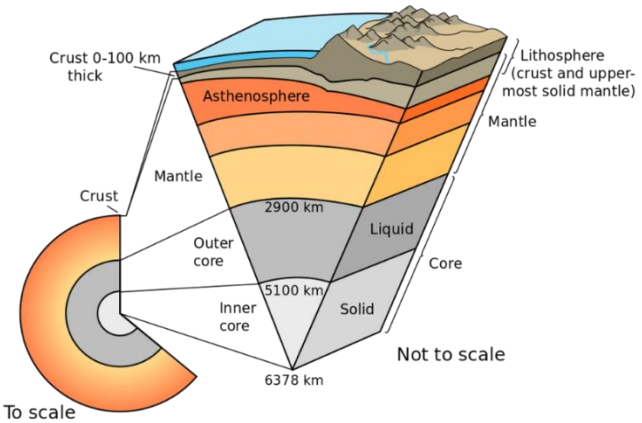
1. Ground displacement
2. Floods from dam and levee failures
3. Fires
4. Structural collapse
5. Falling objects
6. Tsunami

- 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. Though the actual quake activity lasts for a few seconds, its effects are devastating provided the magnitude of the quake is more than 5 on the Richter scale.

Frequency of Earthquake Occurrences

- The earthquake with high magnitude can cause heavy damage to the life and property of people. However, not all the parts of the globe necessarily experience major shocks.
- The quakes of high magnitude, i.e. 8+ are quite rare; they occur once in 1-2 years whereas those of 'tiny' types occur almost every minute.

Structure of the Earth



The Crust

- It is the outermost solid part of the earth. It is brittle in nature because during an earthquake it is the crust that break easily causing a fault.
- The thickness of the crust varies under the oceanic and continental areas. Oceanic crust is thinner as compared to the continental crust. The mean thickness of oceanic crust is 5 km whereas that of the continental is around 30 km. The continental crust is thicker in the areas of major mountain systems. It is as much as 70 km thick in the Himalayan region.
- It is made up of heavier rocks having density of 3 g/cm^3. This type of rock found in the oceanic crust is basalt. The mean density of material in oceanic crust is 2.7 g/cm^3.

The Mantle

- The portion of the interior beyond the crust is called the mantle. The mantle extends from Moho's discontinuity to a depth of 2,900 km.
- The upper portion of the mantle is called **asthenosphere**. The word astheno means weak and due to its weakness magma finds way to the surface during volcanic Eruptions. It has a density higher than the crust (3.4 g/cm^3).
- The crust and the uppermost part of the mantle are called **lithosphere**. Its thickness ranges from 10-200 km. The lower mantle extends beyond the asthenosphere. It is in solid state and this layer is also responsible for all of earth's volcanic and seismic activity.

The Core

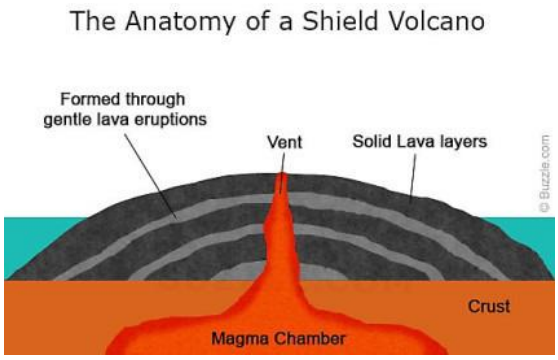
- It is the third and final layer. It is comprised of inner and outer core. The core-mantle boundary is located at the depth of 2,900 km.
- The outer core is in liquid state while the inner core is in solid state.
- The density of material at the mantle core boundary is around 5 g/cm^3 and at the centre of the earth at 6,300 km, the density value is around 13g/cm^3.
- The core is made up of very heavy material mostly constituted by nickel and iron. It is sometimes referred to as the **nife** layer.

Volcanoes and Volcanic Landforms

- A volcano is a place where gases, ashes and/or molten rock material – lava escape to the ground. A volcano is called an active volcano if the materials mentioned are being released or have been released out in the recent past.
- The layer below the solid crust 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.
- The material that reaches the ground includes lava flows, pyroclastic debris, volcanic bombs, ash and dust and gases such as nitrogen compounds, sulphur compounds and minor amounts of chlorine, hydrogen and argon.

Volcanoes: Volcanoes are classified on the basis of nature of eruption and the form developed at the surface. Major types of volcanoes are as follows:

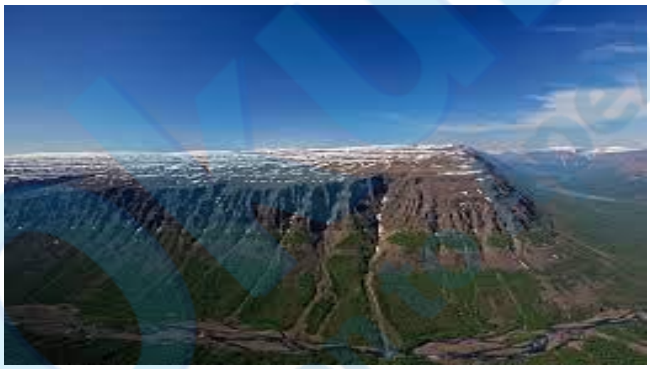
Shield Volcanoes: This are the largest of all the volcanoes on the Earth. The Hawaiian volcanoes are the most famous examples. They resemble the shape of shield as they are wide in diameter and the lava that get out from the volcano is low in viscosity means it is not thick, it is very fluid when erupted. For this reason, these volcanoes are not steep. They become explosive if somehow water gets into the vent; otherwise, they are characterised by low-explosivity. The upcoming lava moves in the form of a fountain and throws out the cone at the top of the vent and develops into cinder cone.



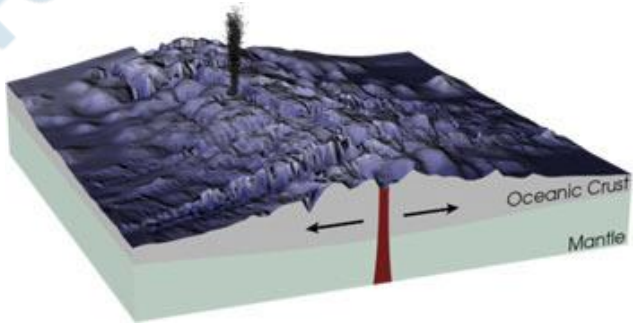
Composite Volcanoes: This volcano is made of multiple eruption, so over time the lava cool down and form thick layer of the crust near vent opening giving it a conical shape. This material accumulates in the vicinity of the vent openings leading to formation of layers, and this makes the mounts appear as composite volcanoes. The lava which comes out from the volcano is having higher viscosity meaning it is thick. These volcanoes often result in explosive eruptions. Along with lava, large quantities of pyroclastic material and ashes find their way to the ground.

Caldera: These are the most explosive of the earth's volcanoes. They are usually so explosive that when they erupt, they tend to collapse on themselves rather than building any tall structure. It is so explosive that the vent opening collapse on itself and create a depression which is called caldera. The explosiveness indicates that the magma chamber is not only huge but it is on close vicinity.

Flood Basalt Provinces: These 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 forming a terrain or landscape. The Deccan Traps from India, presently covering most of the Maharashtra plateau, are a much larger flood basalt province. It is believed that initially the trap formations covered a much larger area than the present.



Mid-Ocean Ridge Volcanoes: It is an underground mountain ranges formed by plate tectonic due to divergent plate boundaries. There is a system of mid-ocean ridges more than 70,000 km long that stretches through all the ocean basins. The central portion of this ridge experiences frequent eruptions.



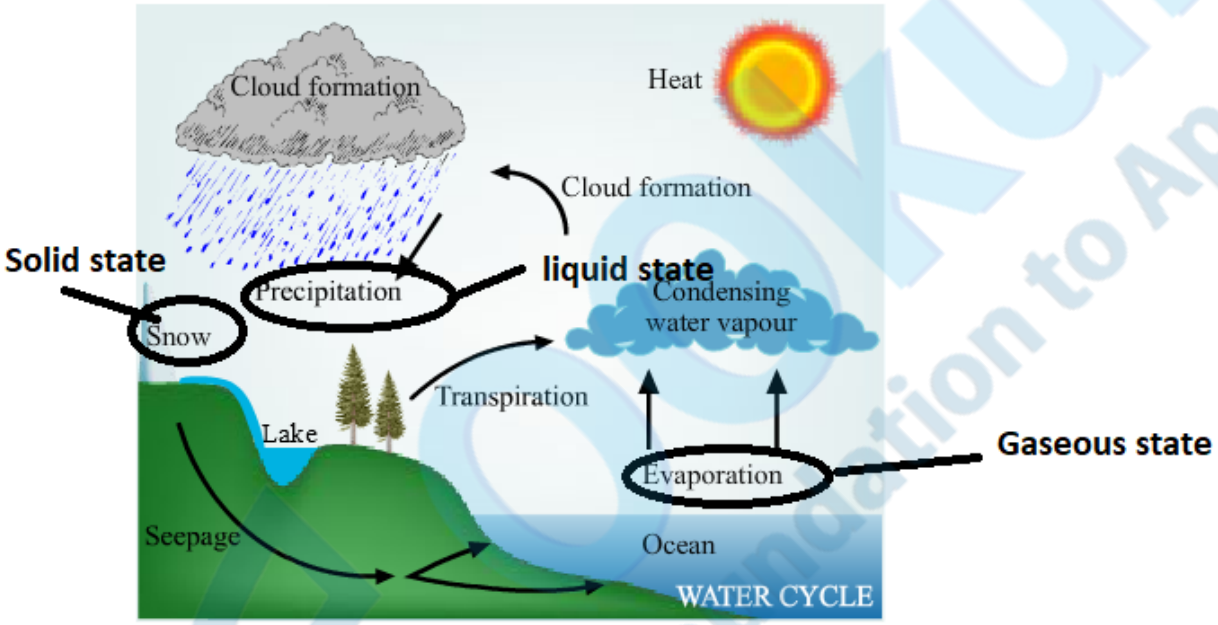
Volcanic Landforms
Intrusive Forms:

- The lava that is released during volcanic eruptions on cooling develops into igneous rocks. The cooling may take place either on reaching the surface or also while the lava is still in the crustal portion.
- Depending on the location of the cooling of the lava, igneous rocks are classified as **volcanic rocks** (cooling at the surface) and **plutonic rocks** (cooling in the crust).

Chapter 11 - Water in the Atmosphere

The air contains water vapour.it is the gaseous state of water. It varies from zero to four per cent by volume of the atmosphere and plays an important role in the weather phenomena.

Water is present in the atmosphere in three forms namely – gaseous, liquid and solid. The moisture in the atmosphere is derived from water bodies through evaporation and from plants through transpiration. Thus, there is a continuous exchange of water between the atmosphere, the oceans and the continents through the processes of evaporation, transpiration, condensation and precipitation



Water vapour present in the air is known as humidity. The actual amount of the water vapour present in the atmosphere is known as the absolute humidity. It is the weight of water vapour per unit volume of air and is expressed in terms of grams per cubic metre. The ability of the air to hold water vapour depends entirely on its temperature. The absolute humidity differs from place to place on the surface of the earth.

The percentage of moisture present in the atmosphere as compared to its full capacity at a given temperature is known as the relative humidity. With the change of air temperature, the capacity to retain moisture increases or decreases and the relative humidity is also affected. It is greater over the oceans and least over the continents.

Note: When calculate humidity do not take account of temperature. only consider the humidity part in the atmosphere not the temperature while in relative humidity temperature take an account while calculating.

The air containing moisture to its full capacity at a given temperature is said to be saturated. It means that the air at the given temperature is incapable of holding any additional amount of moisture at that stage.

The temperature at which saturation occurs in a given sample of air is known as dew point, in other words the point at which air cannot hold the any more water vapour. So, dew is water in the form of water droplets and it exits due to condensation.

Evaporation And Condensation

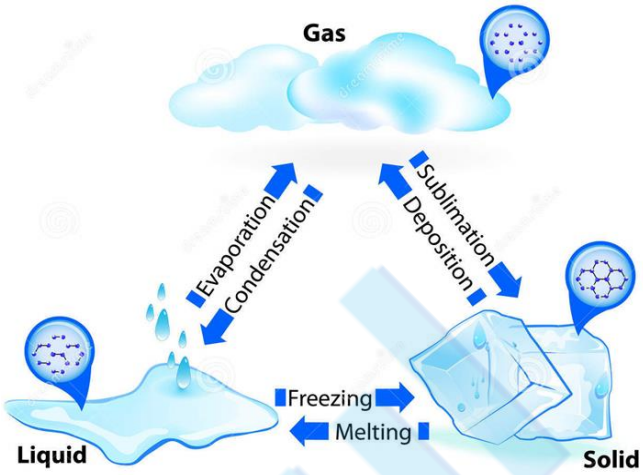
The amount of water vapour in the atmosphere is added or withdrawn due to evaporation and condensation respectively. They are the reason behind the continuous interaction of water in the atmosphere.

Evaporation is a process by which water is transformed from liquid to gaseous state. Heat is the main cause for evaporation. The temperature at which the water starts evaporating is referred to as the latent heat of vapourisation.

Increase in temperature increases water absorption and retention capacity of the given parcel of air. Similarly, if the moisture content is low, air has a potentiality of absorbing and retaining moisture. . Movement of air replaces the saturated layer with the unsaturated layer. Hence, the greater the movement of air, the greater is the evaporation

Condensation is the reverse of Evaporation. The transformation of water vapour into water is called condensation. The transformation of water vapour into water is called condensation.

When moist air is cooled, it may reach a level when its capacity to hold water vapour ceases. Then, the excess water vapour condenses into liquid form. If it directly condenses into solid form, it is known as sublimation or in other ways water-vapour converts into solid form. Example: Hail.



In free air, condensation results from cooling around very small particles termed as hygroscopic condensation nuclei. Particles of dust, smoke and salt from the ocean are particularly good nuclei because they absorb water. Condensation also takes place when the moist air comes in contact with some colder object and it may also take place when the temperature is close to the dew point. Condensation, therefore, depends upon the amount of cooling and the relative humidity of the air

Condensation is influenced by the volume of air, temperature, pressure and humidity. Condensation takes place:

1. When the temperature of the air is reduced to dew point with its volume remaining constant
2. when both the volume and the temperature are reduced
3. when moisture is added to the air through evaporation

However, the most favourable condition for condensation is the decrease in air temperature. After condensation the water vapour or the moisture in the atmosphere takes one of the following forms — dew, frost, fog and clouds

Forms of condensation can be classified on the basis of temperature and location. Condensation takes place when the dew point is lower than the freezing point as well as higher than the freezing point.

Dew

The temperature at which the droplets forms is called dew point and When the moisture is deposited in the form of water droplets on cooler surfaces of solid objects (rather than nuclei in air above the surface) such as stones, grass blades and plant leaves, it is known as dew. The ideal conditions for its formation are clear sky, calm air, high relative humidity, and cold and long nights. For the formation of dew, it is necessary that the dew point is above the freezing point.

Frost

Frost forms on cold surfaces when condensation takes place below freezing point (0°C), i.e. the dew point is at or below the freezing point. The excess moisture is deposited in the form of minute ice crystals instead of water droplets. The excess moisture is deposited in the form of minute ice crystals instead of water droplets.

Fog and Mist

Fog is a cloud with its base at or very near to the ground. When the temperature of an air mass containing a large quantity of water vapour falls all of a sudden, condensation takes place within itself on fine dust particles. Because of the fog and mist, the visibility becomes poor to zero. In fog the visibility is less than 1 km and greater than 1 km is mist because fog is denser than mist.

In urban and industrial centres smoke provides plenty of nuclei which help the formation of fog and mist. Such a condition when fog is mixed with smoke, is described as smog.

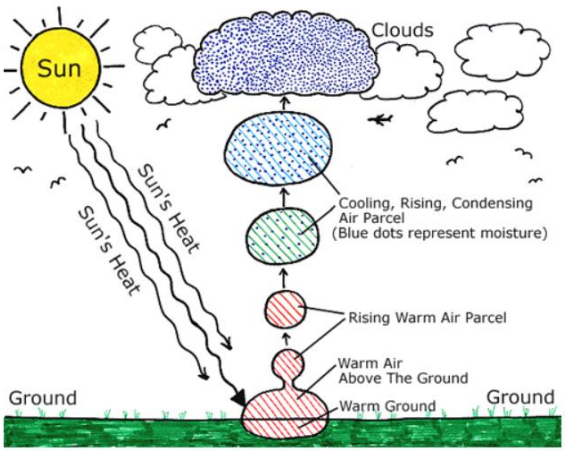
The only difference between the mist and fog is that mist contains more moisture than the fog.

In mist each nuceli contains a thicker layer of moisture. Mists are frequent over mountains as the rising warm air up the slopes meet a cold surface.

Fogs are drier than mist and they are prevalent where warm currents of air come in contact with cold currents. Fogs are mini clouds in which condensation takes place around nuclei provided by the dust, smoke, and the salt particles.

Clouds

Cloud is a mass of minute water droplets or tiny crystals of ice formed by the condensation of the water vapour in free air at considerable elevations. As the clouds are formed at some height over the surface of the earth, they take various shapes.



Types of Clouds

According to their height, expanse, density and transparency or opaqueness clouds are grouped under four types:

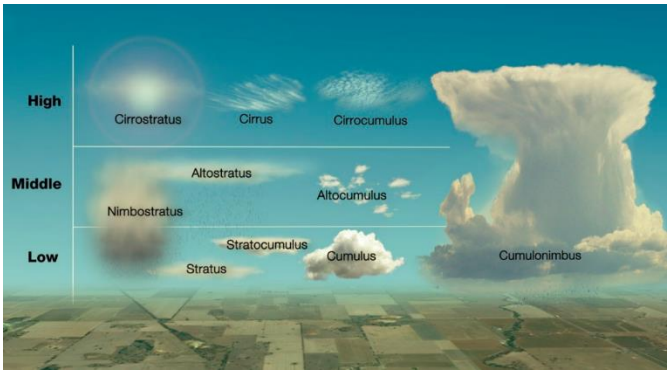
- **Cirrus:** Cirrus clouds are formed at high altitudes (8,000 - 12,000m). They are thin and detached clouds having a feathery appearance. They are always white in colour. As they are at high altitudes the temperature is very low and it made of ice crystal.

- **Cumulus:** They are generally formed at a height of 4,000 - 7,000 m. Cumulus clouds look like cotton wool. They exist in patches and can be seen scattered here and there. They have a flat base. Since, these clouds are bigger than circus cloud therefore it may or may not produce rainfall.

- **Stratus:** these are layered clouds covering large portions of the sky. Also called low altitude clouds as they exit at a height less than 2 km. These clouds are generally formed either due to loss of heat or the mixing of air masses with different temperatures. They appear in white and grey colour as they exit in layers so they don't allow sunlight to pass through it making the day look dull and dark.

- **Nimbus:** Nimbus clouds are black or dark gray. They also in form of layer just like stratus cloud. They form at middle levels or very near to the surface of the earth. These are extremely dense and opaque to the rays of the sun. Sometimes, the clouds are so low that they seem to touch the ground. Nimbus clouds are shapeless masses of thick vapour.

A combination of these four basic types can give rise to the following types of clouds: high clouds –cirrus, cirrostratus, cirrocumulus; middle clouds – altostratus and altocumulus; low clouds – stratocumulus and nimbostratus and clouds with extensive vertical development – cumulus and cumulonimbus.



Precipitation

Precipitation is the direct result of condensation. When the resistance of the air fails to hold them against the force of gravity,

they fall on to the earth's surface. So after the condensation of water vapour, the release of moisture is known as precipitation

This may take place in liquid or solid form. The precipitation in the form of water is called rainfall, when the temperature is lower than the (0°C),, precipitation takes place in the form of fine flakes of snow and is called snowfall.

Moisture is released in the form of hexagonal crystals. These crystals form flakes of snow. Besides rain and snow, other forms of precipitation are sleet and hail, though the hail are limited in occurrence and are sporadic in both time and space.

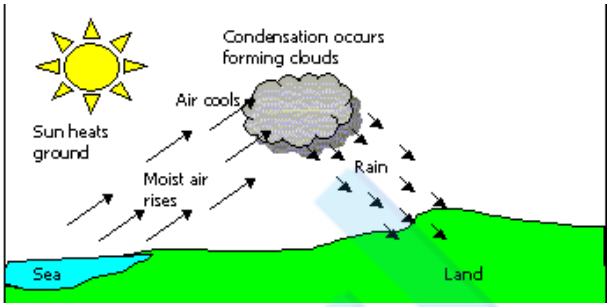
Sleet is frozen raindrops and refrozen melted snow-water. When a layer of air with the temperature above freezing point overlies a subfreezing layer near the ground, precipitation takes place in the form of sleet. Raindrops, which leave the warmer air, encounter the colder air below. As a result, they solidify and reach the ground as small pellets of ice not bigger than the raindrops from which they are formed.

Sometimes, drops of rain after being released by the clouds become solidified into small rounded solid pieces of ice and which reach the surface of the earth are called hailstones. These are formed by the rainwater passing through the colder layers. Hailstones have several concentric layers of ice one over the other.

Types of Rainfall

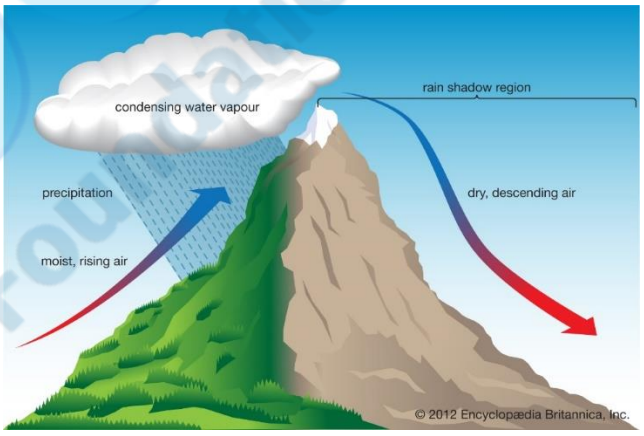
On the basis of origin, rainfall may be classified into three main types:

- **Convectional Rain:** it occurs when the sun heats up the land surface and it also heat the surrounding air, when the warm air rises and rising warm air form convectional current. As it rises, it expands and loses heat and consequently, condensation takes place and cumulous clouds are formed. Once the clouds are formed subsequently rainfall takes place with thunder and lightning but this does not last long. Such rain is common in the summer or in the hotter part of the day. It is very common in the equatorial regions and interior parts of the continents, particularly in the northern hemisphere.



- **Orographic Rain:** it is related to mountain, When the saturated air mass comes across a mountain, it is forced to ascend and as it rises, it expands; the temperature falls, and the moisture is condensed.

The chief characteristic of this sort of rain is that the windward slopes receive greater rainfall. After giving rain on the windward side, when these winds reach the other slope, they descend, and their temperature rises.



Then their capacity to take in moisture increases and hence, these leeward slopes remain rainless and dry. The area situated on the leeward side, which gets less rainfall is known as the rain-shadow area. It is also known as the relief rain.

- **Cyclonic Rain:** under this rain occur due to cyclonic activity. Cyclone is a large scale of air mass that rotates around low-pressure zone.

World Distribution of Rainfall

Different places on the earth's surface receive different amounts of rainfall in a year and that too in different seasons. As we proceed from the equator towards the poles, rainfall goes on decreasing steadily. The coastal areas of the

world receive greater amounts of rainfall than the interior of the continents. The rainfall is more over the oceans than on the landmasses of the world because of being great sources of water.

Between the latitudes 350 and 400 N and S of the equator, the rain is heavier on the eastern coasts and goes on decreasing towards the west. But, between 450 and 650 N and S of equator, due to the westerlies, the rainfall is first received on the western margins of the continents and it goes on decreasing towards the east.

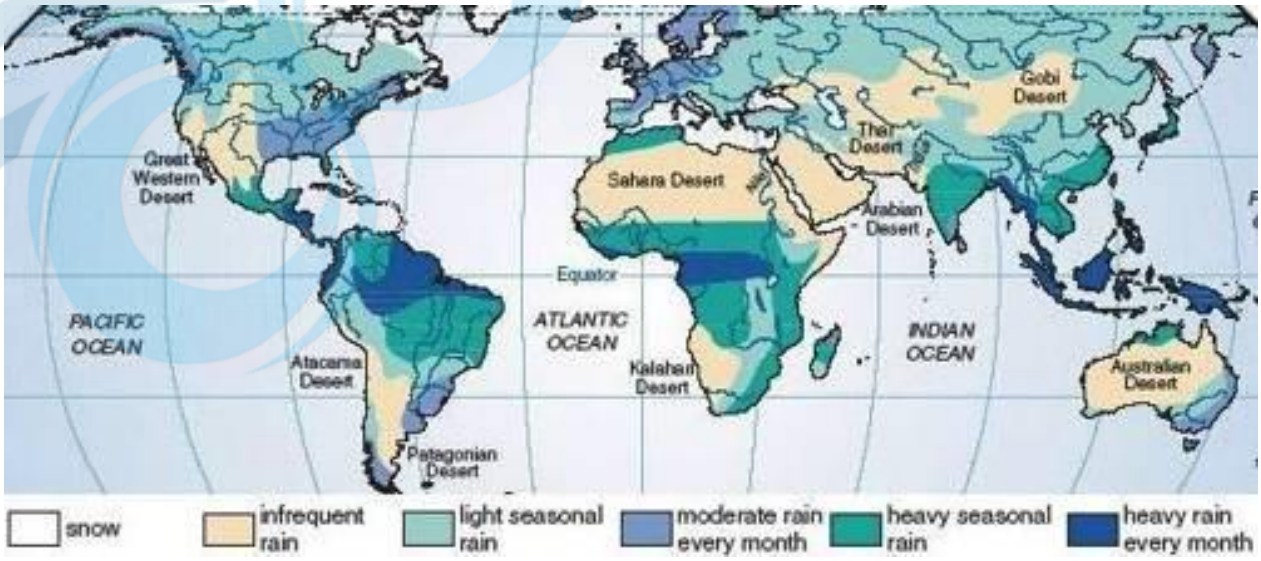
Wherever mountains run parallel to the coast, the rain is greater on the coastal plain, on the windward side and it decreases towards the leeward side

On the basis of the total amount of annual precipitation, major precipitation regimes of the world are identified as follows

The equatorial belt, the windward slopes of the mountains along the western coasts in the cool temperate zone and the coastal areas of the monsoon land receive heavy rainfall of over 200 cm per annum. Interior continental areas receive moderate rainfall varying from 100 - 200 cm per annum. The coastal areas of the continents receive moderate amount of rainfall.

The central parts of the tropical land and the eastern and interior parts of the temperate lands receive rainfall varying between 50 - 100 cm per annum. Areas lying in the rain shadow zone of the interior of the continents and high latitudes receive very low rainfall-less than 50 cm per annum.

Seasonal distribution of rainfall provides an important aspect to judge its effectiveness. In some regions rainfall is distributed evenly throughout the year such as in the equatorial belt and in the western parts of cool temperate regions.



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