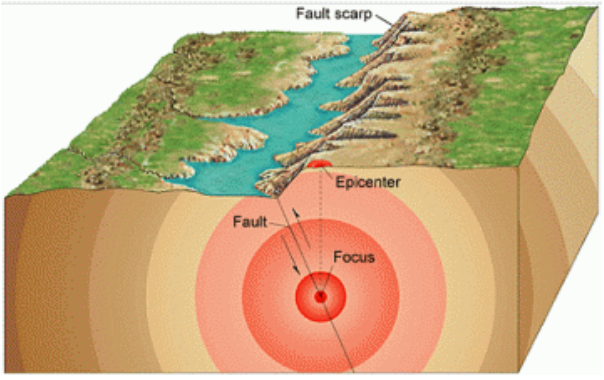
Contents

In Earthquake, there is a sudden release of energy in the Earth's crust, which leads to a series of motions because of the waves created due to this energy released. The waves are called **Seismic Waves**. These seismic waves originate in a limited region and spread in all directions.

Understanding Earthquake



Hypocenter:

The point, where earthquakes are generated first, is called focus or hypocenter. A hypocenter is below the surface, where the first rock displaces and creates the fault. It is also known as Focus. Please note that in nuclear explosion, the point where the bomb explodes is called Ground Zero.

Epicenter:

It is the point on the Earth's surface that is **directly above the hypocenter or focus.** This is the point where the shock waves reach the surface. Hypocenter is below ground, Epicenter is on surface. In Nuclear Explosion, Ground Zero is used for both underground or above ground depending upon the nuclear explosion.

Earthquakes originate at depths ranging from about 5 to 700 kilometers. Nearly go percent of all earthquakes occur at depths of less than 100 km. Most destructive earthquakes originate at even shallower depths.

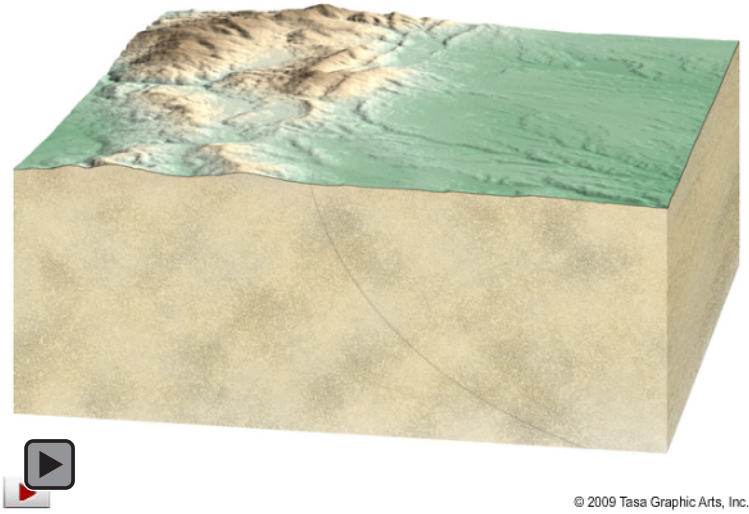
Seismic Waves

The waves generated by the earthquake are called Seismic waves. The study of earthquake and seismic waves is called Seismology and the researchers are called Seismologists. The speed of the seismic waves varies. In earth crust their speed is around 2-8 kilometers per second, while in mantle the speed is up to 13 kilometer per second.

- The instruments to measure the seismic wave fields are **seismograph, geophone, hydrophone and accelerometer.**

Geophone
Geophone is an instrument which converts the ground movement or displacement into voltage, which can be recorded as deviation of measured voltage. The deviation of measured voltage from the base line is called the seismic response and is analyzed for structure of the earth.
Hydrophone
A hydrophone can "listen" to sound in water. It is generally used to listen underwater sounds. It gives poor performance but, still somewhat useful in reflection seismology.
Accelerometer
Accelerometer is a device that measures proper acceleration. In vehicles, they are uses to speed acceleration. The Quake-Catcher Network run by Stanford University and UC Riverside that aims to use computer based accelerometers to detect earthquakes.

Please click the Play Button to play the graphics



Seismograph

Seismographs or seismometers record the motions of the ground including those of seismic waves. Another instrument with similar name is seismoscopes, which only record that a motion has occurred.The seismographs record the motions on paper.

- ***Houleng Didong Yi*** was the first seismograph developed by the Chinese in 123 AD .
- Early seismographs used magnets suspended in a coil, which on movement generates electric field.
- Today's seismographs are digital instruments; they are able to sense ground motion over a wide range of frequencies, from thousands of seconds to less than a hundredth of a second.
- Worldwide Standard Seismograph Network (WWSSN) is located in Albuquerque, USA. It is a network consisting of over 120 seismographs in 60 countries.

Aftershock and Foreshock

A smaller earthquake that occurs after a large earthquake in the same area is called aftershock. So aftershock is smaller than the main shock. If an aftershock is larger than the main shock, the aftershock is re-designated as the main shock and the original main shock is re-designated as a foreshock. Aftershocks are due to adjustment of the plates. **Gutenberg-Richter law** gives the relationship between the magnitude of the shock and total number of earthquake in the given region. Many earthquakes striking in a relatively short period of time in the same area are called Earthquake Swarms. A large number of earthquake shocks are known as Earthquake Storms.

Seismite is a sedimentary rock beds, which are disturbed by seismic waves from earthquakes, most Seismite are ball-and-pillow structures.

How The Earthquakes Occur?

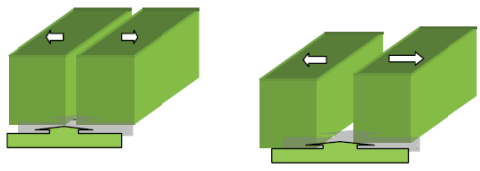
The Theory of plate tectonics explains that earth's crust is formed by a number of large plates that move very slowly in various directions on the earth's surface. These plates are 60-200 km thick and float on top of a more fluid zone, much in the way that icebergs float on top of the ocean. Most earthquakes occur near a boundary between two plates. As one plate pushes past or moves over another, great stresses build up in the rock along the edges of the plates because friction prevents them from sliding past each other. Subsequently, the stresses become great enough so that the rocks can rupture. The edges of the plates slip a short distance in different directions, causing an earthquake. Greater the stresses, greater is the resulting earthquake. Some earthquakes are caused by the movement of lave beneath the surface of the earth during volcanic activity.

Plate Movements

The movements are of three kinds:

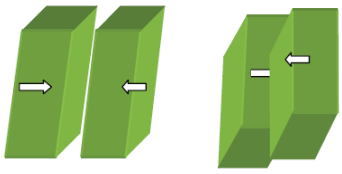
Divergent:

In divergent movements the plates move apart from each other as shown below. This is most common type of movement in mid-oceanic zones.



Convergent

In divergent movements the plates move towards each other and the border overlap. This is most common type of movement in subduction zones where the dense oceanic plates collide and slide beneath the continental plates.



Transformational

In this type of movement the plates move in opposite side, on parallel.

Types of Seismic Waves

The movement between plates and along faults is not smooth. They move in jerks, giving rise to seismic waves. They are divided into two broad categories viz. Body Waves and Surface Waves.

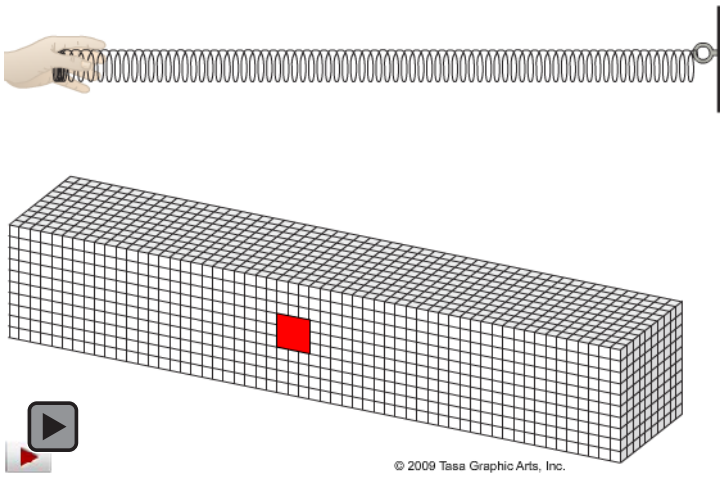
Body Waves

In Body waves the speed decreases with increasing density of rock and increases with increasing rock elasticity. Rock elasticity increases faster than density with depth. There are two kinds of Body waves:

1. Primary Waves or P-waves:

The Primary waves are Compression waves that vibrate parallel to the direction of wave movement and travel through solid, liquid and gas. These are the fastest seismic wave. They are also called push waves or longitudinal waves are similar to sound waves in nature.

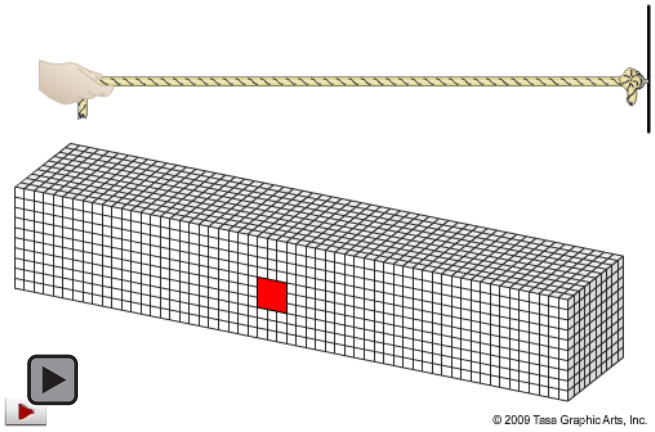
- They have the shortest wavelength among the four .
- The velocity of P waves is 5 to 7 km per second .
- They can travel through liquids and solids but travel faster in denser solid materials.



Secondary waves or S-waves:

These waves create vibrations perpendicular to the direction of wave movement. The S waves only travel through solids as liquids I gases have no shear strength.

- The S waves or secondary waves or **Transverse Waves** are in nature it is similar to light wave.
- Also known as Shock waves or Shear Waves .
- They have a medium wavelength and are also called shake or shear waves .
- The vibrations are transverse or at right angles to the direction of propagation of waves and can travel only through solid and not through liquids .
- S waves is the main evidence to assume that the earth's core liquid .
- Their velocity is 3 to 4 km per second.



Surface Waves:

2. Rayleigh Waves or L-waves

L Waves or Surface Waves travel near the earth's surface and within a depth of 30-32 kilometers from the surface. These are also called Rayleigh waves after Lord Rayleigh who first described these waves .

- Behave like water waves with elliptical motion of material in wave.
- Generally slower than Love waves.

3. Love waves

Love waves make the ground vibrate at right angles to the direction of waves .

- They are a variety of S-waves where the particles of an elastic medium vibrate transversely to the direction of wave propagation, with no vertical components.
- Involve shear motion in a horizontal plane. Most destructive kind of seismic wave.

Which among the following waves give evidence that Earth has a liquid Core?

1 P-waves:
2. S-Waves
3. L -Waves
4. Love Waves

Answer of the question is S waves. Because S waves cannot traverse through liquids, giving rise to S waves shadow or Earthquake Shadow, which is explained in this module.

Which among the following waves reach the seismograph first?

a. P-waves:
b. S-Waves
c. L -Waves
d. Love Waves

Please note that p-waves are the first to reach any seismograph.

P-Waves

P-waves are the same thing as sound waves. They move through the material by compressing it, but after it has been compressed it expands, so that the wave moves by compressing and expanding the material as it travels. Thus the velocity of the P-wave depends on how easily the material can be compressed (the incompressibility), how rigid the material is (the rigidity), and the density of the material. That is why the P-waves are called Compressional also. P-waves have the highest velocity of all seismic waves and thus will reach all seismographs first.

What is the Minimum Number of seismographic stations required to determine the location of an earthquake?

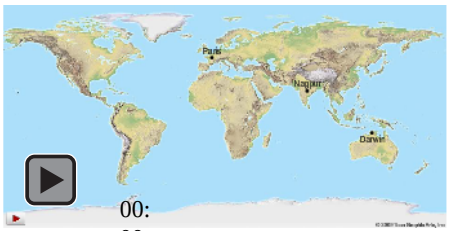
A. One
B. Two
C. Three
D. Four

Answer of this question is Three.

To determine the location of an earthquake, the following two things of info are required:

1. Recorded seismograph of the earthquake from at least three seismographic stations at different distances from the epicenter of the quake.
2. Time it takes for P-waves and S-waves to travel through the Earth and arrive at a seismographic station.

These information's have been collected for a long time (80-90 years) and now the database of the info for all time zones helps the seismographers to analyze the location of the earthquake. As we know that the P waves reach the to the seismographs first at a station, the difference between the time of P waves and S waves is called S-P Interval. The S-P interval increases with increasing distance from the epicenter. At each station a circle on a map can be drawn which has a radius equal to the distance from the epicenter. Following graphic shows this:



Click on this Button

Measuring Earthquake Intensity

Richter Magnitude Scale

Richter magnitude scale is a base-10 logarithmic scale obtained by calculating the logarithm of the shaking amplitude of the largest displacement from zero on **Wood-Anderson torsion** seismometer. It was developed in 1935 by Charles Richter in partnership with Beno Gutenberg, both of the California Institute of Technology.

A difference between Richter scale 4.0 and Richter scale 5.0 denotes that:

A. There is a 10 fold increase in energy
B. There is a 10 fold increase in the area affected
C. There is a 10 fold increase in the waves sizes
D. There energy of Earth quake doubles.

Answer of this question is C

Sometimes, we read that an increase in 1 in the Richter magnitude, there is a tenfold increase in the size of the earthquake. This is incorrect. The correct fact is that increase in 1 in the Richter magnitude, there is a tenfold **increase in the size of the waves or shaking amplitude**. The Richter scale 5.0 is 10 times more shaking amplitude of 4.0. But there is a huge difference in energy. The energy release of an earthquake denotes the destructive power. It scales with $\frac{3}{2}$ power of the shaking amplitude. A difference in magnitude of 1.0 is equivalent to a factor of 31.6. This is shown by the following equation:

$$(10^{1.0})^{\frac{3}{2}} = 31.6$$

A difference in magnitude of 2.0 is equivalent to a Factor of 1000. It is shown below:

$$(10^{2.0})^{\frac{3}{2}} = \frac{100^3}{100^2} = \frac{1000000}{10000} = 1000$$

Following table shows the exponential increase in earthquake energy on Richter scale:

Richter Approximate Magnitude	Approximate TNT for Seismic Energy Yield
1.0	474 g (1.05 lb)
2.0	15.0 kg (33.1 lb)
3.0	474 kg (1050 lb)
4.0	15.0 metric tons
5.0	474 metric tons
6.0	15.0 kilotons
7.0	474 kilotons
8.0	15.0 megatons
9.0	474 megatons
10.0	15.0 gigatons

Examples of the most devastating Earthquake recorded are Indian Ocean Earthquake 2004, which caused the 2004 Indian Ocean Tsunami and the **Valdivia earthquake** (Chile), 1960. The Indian Ocean Earthquake was of 9.3 intensity in Richter scale while the **Valdivia earthquake of Chile was 9.5**. An earthquake of 10.0 on Richter scale has never been recorded by Humankind.

The 2010, Haiti Earthquake was 7.0 on the Richter scale.

Moment magnitude scale

The Richter scale is denoted by $\mathbf{M_L}$. This scale was replaced in 1970s by the new Moment magnitude scale which is denoted as $\mathbf{M_w}$. The scale is almost same and media uses the same term "Richter Scale" for the new MMS also. This is because medium earthquakes such as 5.0 are equal on both the scales.

A new type of scale called Moment magnitude scale is nowadays being used to measure the magnitude of the Earthquakes. In this context, consider the following statements:

1. The Moment magnitude scale is used for larger magnitude earthquakes while Richter scale is used for smaller magnitude earthquakes.
2. The Moment magnitude scale has no upper limit while the Richter scale has an upper limit.

Which among the above statements is / are correct?

Answer: Both are correct statements.

The Richter scale was based on the ground motion measured by a particular type of seismometer at a distance of 100 kilometers from the earthquake, and Richter scale has a highest measurable magnitude. The large earthquakes have a similar magnitude of around 7.0 on Richter scale. The Richter scale measurement is also unreliable for measurements taken at a distance of more than about 600 kilometers from the earthquake's epicenter. This problem is solved by the MMS (Moment magnitude scale). The Moment magnitude scale does not uses the ground motion, but used the physical properties of the Earthquake such as seismic moment. The scale was introduced by Thomas C. Hanks and Hiroo Kanamori in 1979. The US Geological survey uses the Moment magnitude scale for all large earthquakes. Drawback: Moment magnitude scale deviates at the low scale Earthquakes.

Medvedev-Sponheuer-Karnik scale (MSK-64)

Medvedev-Sponheuer-Karnik scale denoted by MSK or MSK-64, is a macro seismic intensity scale which is used to evaluate the severity of ground shaking on the basis of observed effects in an area of the earthquake occurrence. It was proposed by Sergei Medvedev (USSR), Wilhelm Sponheuer (East Germany), and Vft Karnfk (Czechoslovakia) in 1964.

MSK 64 Scale
Not perceptible
II. Hardly perceptible
III. Weak
IV. Largely observed
V. Fairly strong
VI. Strong
VII. Very strong
VIII. Damaging
IX. Destructive
X. Devastating
XI. Catastrophic

- MSK-64 is used in India, Israel, Russia, and throughout the Commonwealth of Independent States.
- In India the seismic zoning has been done on the basis of this scale.
- This scale has 12 intensity degrees expressed in Roman numerals, which are shown in the table shown in the left.

Earthquake Belts

There are two major belts of earthquakes in the world. They are as follows:

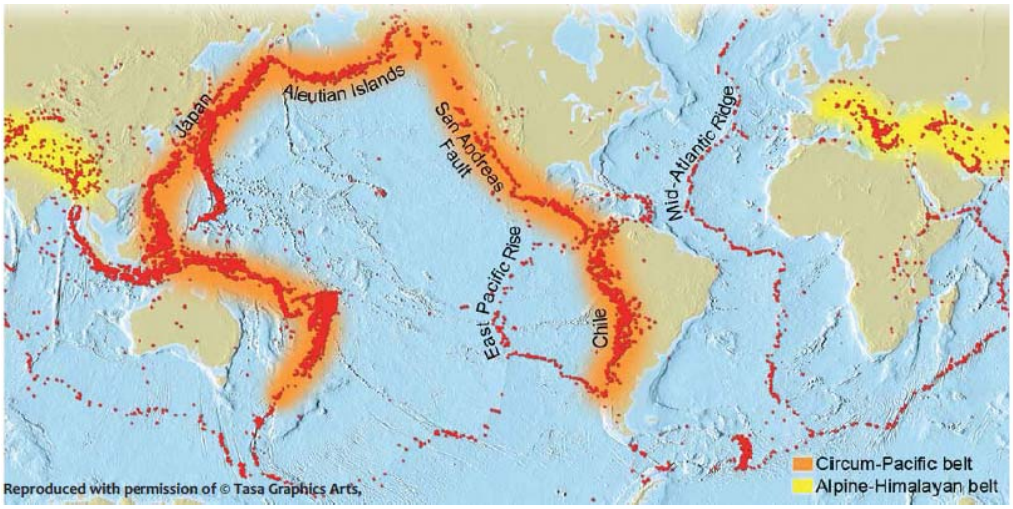
A. Circum-Pacific Belt:

This belt is along a path surrounding the Pacific Ocean This zone included the regions of great seismic activity such as Japan, the Philippines, and Chile. This path coincides with the "Pacific Ring of Fire".

B. Alpine-Himalayan Belt

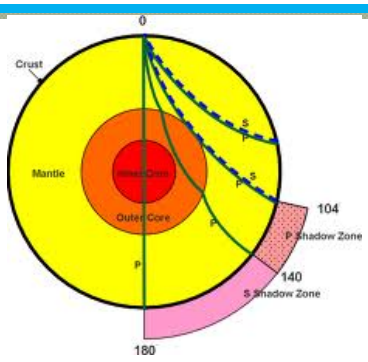
Another major concentration of strong seismic activity runs through the mountainous regions that flank the Mediterranean Sea and extends through Iran and on past the Himalayan Mountains. This zone of frequent and destructive earthquakes is referred to as the Alpine-Himalayan belt.

Following Picture shows the distribution of these belts:



Shadow Zones

As we know that the waves of the Earthquakes get recorded at the seismographs located at far of locations, there are some points / areas where the waves are not reported. These are called Shadow Zones. Each earthquake has its own shadow zone. Following graphic shows the shadow zone:



The shadow zone of P-waves appears as a band around the earth between 104°and 140° away from the epicenter. Beyond the 140° the seismographers have not recorded the Arrival of S waves. The zone between 104° and 140° is called a shadow zone; The entire area beyond the 140° does not receive the S waves. So please note the following point:

- The area between 104° and 140° is the shadow zone of both kinds of waves. This area is narrowly defined. It may be l05° to 145° or even 150°, however most sources site is 104" to 140°.

Types of earthquakes

There are several types of earthquakes they are as follows:

Tectonic Earthquakes: Tectonic Earthquakes are most common and generated due to folding, faulting plate movement.

Volcanic Earthquakes: Earthquake associated with volcanic activity are called volcanic earthquake. These are confined to areas of volcanoes and pacific ring of fire is best example of these types of earth Quakes.

Collapse Earthquakes: They are evident in the areas of intense mining activity, sometimes as the roofs of underground mines collapse causing minor tremors.

Explosion earthquakes: This is a minor shock due to the explosion of the nuclear devices.

Reservoir Induced Earthquakes: Large reservoirs may induce the seismic activity because of large mass of the water. They are called reservoir induced earthquakes

Seismic Zoning of India

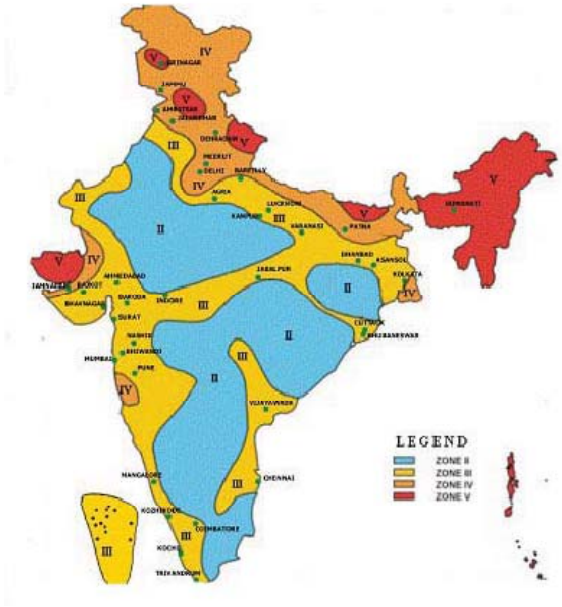
Indian subcontinent has a long history of devastating earthquakes, partially due to the fact that India is driving into Asia at a rate of approximately 47 mm/year. More than 50% area of Indian Subcontinent is vulnerable to earthquakes.

IS 1893:2002:

IS 1893:2002 is the latest code of Bureau of Indian Standards (BIS) which lays down the criteria of for earthquake resistant design of structures. It has grouped the country in four seismic zones viz. Zone-II, -Ill, -IV and -V unlike its previous version which consisted of five zones for the country. This zoning has been done on the basis of MSK-64 scale and a IS code Zone factor has been assigned by the BIS to each of them.

The zone factor of 0.36 is indicative of effective (zero period) peak horizontal ground acceleration of 0.36 g (36% of gravity) that may be generated during MCE level earthquake in this zone. They are presented in the following table with IS code.

Seismic Zoning of India		
MSK-64	Seismic Zone in India	Zone Factor
VI. Strong	Zone II This region is liable to MSK VI or less and is classified as the Low Damage Risk Zone.	0.10
VII. Very strong	Zone III The Andaman and Nicobar Islands, parts of Kashmir, Western Himalayas fall under this zone. This zone is classified as Moderate Damage Risk Zone which is liable to MSK VII.	0.16
VIII. Damaging	Zone 4 This zone is called the High Damage Risk Zone and covers areas liable to MSK VIII. The Indo-Gangetic basin and the capital of the country(Delhi, Jammu)and Bihar fall in Zone 4.	0.24
IX. Destructiv	Zone 5 Zone 5 covers the areas with the highest risk zone that suffers earthquakes of intensity MSK IX or greater. It is referred to as the Very High Damage Risk Zone. The state of Kashmir, Punjab,the western and central Himalayas, the North-East Indian region and the Rann of Kutch fall in this zone.	0.36



Some Earthquakes in India

The Himalayan frontal arc is one of the seismically active regions of the world. The peninsular shield of India has generated some remarkable earthquakes.

- The Latur earthquake in the heart of the Indian shield is considered as a typical SCR (stable continental regions) earthquake.
- The largest earthquake induced by an artificial reservoir occurred at Koyna, Maharashtra.
- The 1819 Runn of Kutch earthquake (M =8.0) is one of the largest intraplate events that produced a surface scarp about 100 km long.
- The Himalayan mountain range is the dramatic outcome of the collision of Indian and Eurasian plates, some 40 million years ago (MYA).
- The Himalayan collision zone has been marked by intense seismic activity. Four great earthquakes (1897 Assam,1905 Kangra; 1934 Bihar-Nepal and 1950 Assam) occurred here in a short span of 53 years.

- The frequent moderate earthquakes and the infrequent great earthquakes suggest that episodic slippage is continuing.
- These ongoing processes also imply that future great earthquakes can be expected in the un ruptured parts of the Himalayan front.
- The 1991 Uttarkashi earthquake (M 6.5) which occurred in the Tehri region in Gharwal Himalaya shook the north-central India. Though, it was a moderate earthquake yet it had drawn a lot of attention due to its proximity to the high Tehri dam.
- On September 30, 1993, the Latur (Killari), Maharashtra earthquake was the most devastating earthquake in the country. Over 10,000 lives were lost in this earthquake and several villages were destroyed. With a magnitude 6.3 and focal depth less than 10 km, this earthquake is similar to other moderate events in the Australian and Canadian shields.
- Seismicity associated with the Shivaji Sagar lake formed by the Koyna dam is considered to be an example of earthquake activity triggered by reservoirs. An earthquake of magnitude 6.3 (1967) and many of magnitude >5.0, have occurred at Koyna.
- May 22,1997, an earthquake of magnitude 6.0 occurred in the Jabalpur area, Madhya Pradesh.
- On January 26, 2001, Bhuj earthquake (Mw 7.7) in Gujarat devestated the town and surrounding areas. Over 20,000 people were dead and more than 200,000 were injured. Nearly 400,000 houses were destroyed and twice as much damaged.
- The 2011 Sikkim earthquake was a magnitude 6.9 (Mw) earthquake centered within the Kanchenjunga Conservation Area, near the border of Nepal and the Indian state of Sikkim on Sunday , 18 September 2011. The earthquake was felt across northeastern India, Nepal, Bhutan, Bangladesh and southern Tibet.

VOLCANOES

What is a Volcano?

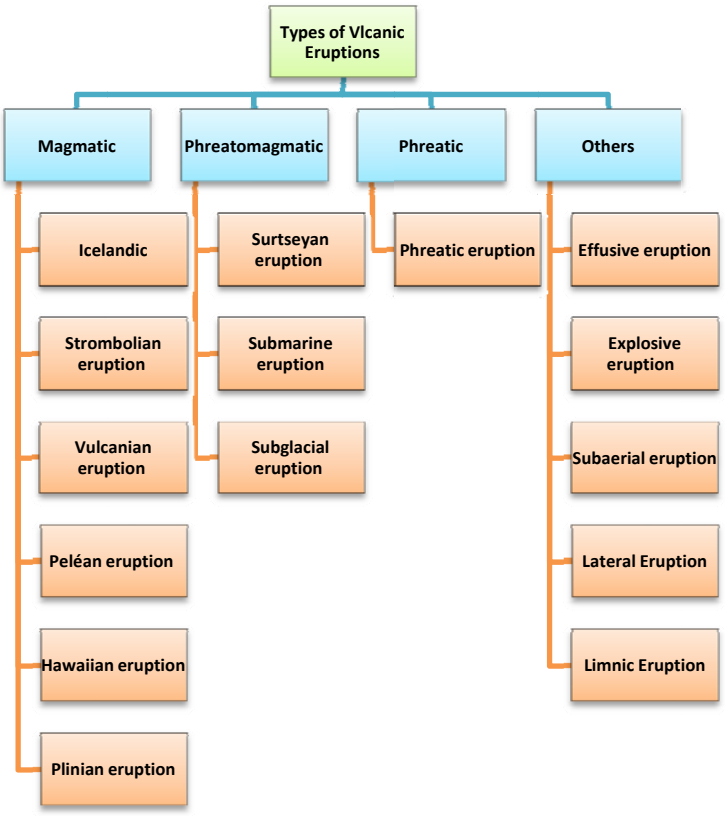
An opening or vent through which the magma, molten rocks, ashes, gases and other volatiles erupt on the surface of Earth is called a Volcano. ***Vulcan*** is Greek God of beneficial and hindering fire. A festival was celebrated in Athens devoted to *Vulcan* on August 23, and the name of the festival was **Volcanalia**. Vulcanization is another term derived from the name of Vulcan God.

Vulcanization is adding sulfur or other curatives to rubber or other polymers to make them more durable. The rubber so produced is called Vulcanite or ebonite.

Vulcano is the name of an island near Sicily, the largest island in the Mediterranean Sea and an autonomous region of Italy. The most known types of Volcanoes are conical mountains which spit law and poisonous gases. But there are other types of Volcanoes. The Volcanoes can be divided in the basis of Type of Eruption, Material erupted & Periodicity of eruption.

Types of Volcanoes by Volcanic Eruption

There are three major categories of the volcanic eruptions. The magmatic eruptions involve the decompression of gas within the magma. This decompression of the gas propels it outward. In Phretomagmatic eruptions involves compression of the gas within the magma. Another is Phreatic eruption which involves superheating of steam via contact with Magma. In Phreatic eruption, there is no magmatic release and they cause the granulation of the rocks. Apart from this there are other types of eruptions which sometimes don't seem to be Volcanic Eruptions. The following graphic shows this classification.



Magmatic Eruptions

When Magma, the mixture of rocks, volatiles and solids erupts in a fissure. it is called magmatic eruption. The following are main types:

Icelandic Eruption: The free flowing basaltic lava is released is a large quantity. The eruption is poor in gas and issues a great volume of lava. The lava flows as sheets over a large area to build up plateaus. Basalt is a dense volcanic rock, about 50 percent of which is silica. In India, the Deccan Plateau is a Lava Plateau, which was formed

Strombolian Eruption:

The name is derived after the Italian Volcano Mount Stromboli. They are also known as summit craters. They are moderate and exhibit continuous explosions. Mostly light colored clouds are seen as in the picture. **Mount Stromboli is located in the Stromboli island, and is best known as "Light House of the Mediterranean".**

Vulcanian Eruption:


Mount Stromboli, Italy image: wikimedia

These types of volcanoes allow the gas to compress beneath the magma and this result in violent eruption over quite periods. The volcano ejects bombs, and the lava flows after the main explosion giving rise to a layer of lava and ash. The clouds formed are cauliflower shaped and grows vertically and often result in acid rains. Strombolian Eruption and Vulcanian eruptions are sometimes used synonymously. The only major difference is that Vulcanian Eruption is more violent than the Stombolian eruption and eruption occurs over long periods.

Peléan eruption

The Peléan eruption results from the highly viscous lava and the main characteristics are **formation of lava domes**. There is a presence of **glowing cloud of hot volcanic ash**. This term is derived for 1902 explosion of Mount Pelée, also known as Bald Mountain located in the Caribbean. The Volcanic cones of such Volcanoes are composed of layers of volcanic ash and hardened lava.

Hawaiian eruption

Hawaiian eruption is the main characteristic of Hawaiian Volcanoes. This is the most common type of eruption in most hotspot volcanoes. These volcanoes have lower water content and that is why they are more peaceful in eruptions. The lava is basalt in composition. These eruptions produce Fire Mountains and the amount of as is minor.

Plinian Eruption:

Plinian Eruptions are synonymous with **Vesuvian Eruption**. The term derived after the name of Pliny. **Pliny, the younger** was a lawyer, writer and magistrate of ancient Rome. His uncle was **Pliny, the elder**. **Pliny, the elder** was the same writer who had written about Indian Emperor Chandragupta Maurya. Seleucus, the successor of Alexander the Great was in good terms with Chandragupta Maurya and the details are provided by **Pliny, the elder**. **Pliny the elder** was killed in the great eruption of the Mount Vesuvius in Italy on August 24, 79AD. The account of his death was provided by Pliny the Younger. The plumes are very high range varying from 20-25 kilometers.

Phreatomagmatic eruptions

They are juvenile eruptions mostly occur due to interaction of water and magma. The theraml contraction of the particles when come in touch with water the rapid cooling follows which results in this type of explosion. These may occur under the sea when basalt erupts and comes in touch with the water to give rise to the Pillow basalts, rocks in the pillow shape.

Surtseyan eruption

Surtseyan eruption takes place in **shallow seas and lakes**. They are named after the Surtsey, a volcanic island off the coast of Iceland.

Submarine eruption

Submarine eruption occurs under an ocean. These are the most common eruptions on earth. However, they are not documented because of the difficult monitoring.

Subglacial eruption

Subglacial eruptions occur under the ice. **They are also known as Tuya**. The examples of these types of eruptions are Eruption of a Volcano under the Antarctica ice sheet and Hudson Mountains. The former occured 2200 years ago.

2010, Eyjafjallajökull eruption in Island was a Subglacial eruption.

Pheratic Eruptions:

These eruptions usually occur with extremely loud explosions. The explosions are mostly accompanied by carbon dioxide or hydrogen sulfide gas emissions which prove fatal to the organisms around. This eruption is also known as steam-blast eruption and most common example is 1979 explosion in the Java Island, which killed more than 100 people.

Other Types of Eruptions:

Effusive eruption causes the lava to flow on ground slowly, and it travels slowly away from the site of eruption. Sub aerial eruptions occur on the surface in contrast with the submarine or subglacial eruption. Limnic Eruptions occur below the bed of lakes and is called Lake Overturn. The gases (mostly CO2) suddenly erupt from the bed of the lake making the water and environment poisonous killing animals. The lake tsunamis are caused by Limnic disruptions sometimes. **Lake Monoun & Lake Nyos in Cameroon** have suffered this kind of eruptions in near past.

Classification of Volcanoes on the basis of Periodicity of Eruption

There are 3 kinds of Volcanoes on the basis of frequency of eruption. Active, Dormant and Extinct. Active Volcanoes erupt frequently and mostly located around Ring of Fire. The Mount. Stromboli is an active volcano and it produces so

much of Gas clouds that it is called Light house of Mediterranean. Other examples are Eyjafjallajökull in island, which erupted in 2010 recently, Mount St. Helens located in Washington USA, Mt. Etna located in Sicily.

Dormant Volcanoes are those who are not extinct but not erupted in recent history. Mount Kilimanjaro, located in Tanzania which is also the highest mountain in Africa is known to be a dormant Volcano. **The dormant volcanoes may erupt in future.**

Extinct or inactive volcanoes have not worked in distant geological past. In most cases the crater of the Volcano is filled with water making it a lake.

Some Terms Related to Volcanism

Volcanic Ash:

The Ash from the Volcanoes is hard and abrasive type which is made up of rock particles, minetals and Volcanic glass fragments. The cloud made by the Volcanic Ash is called Ash Cloud. When this ash falls on the ground, it is called Volcanic Ash Fall. The clouds are called Avalanches sometimes.

Volcanic Bomb

Pieces of Viscous lava often 2.5 inch size are ejected from the volcanoes. They are viscous rounded shaped half semisolid pieces called Volcanic Bombs. They are either round or spindle shaped or ribbon shaped. Sometimes referred to as Volcanic Blocks, however, Volcanic blocks are thought almost same size, are solid. The smaller particles less than 2.5 inch are called **Lapilli.** The pieces of rocks that erupt violently are also called ballistic fragments.

Tephra

The Tephra is all the volcanic material such as Ash, Plumes, Volcanic Bombs, Volcanic Blocks, lapilli etc.

Cinder Cone:

A cone shape hill of volcanic fragments that accumulate around and downwind from a volcanic vent is a cinder cone. There is usually a bowl-shaped crater at the top. As the gas-filled lava erupts into the air, the lava fragments and forms cinders.

Composite volcano

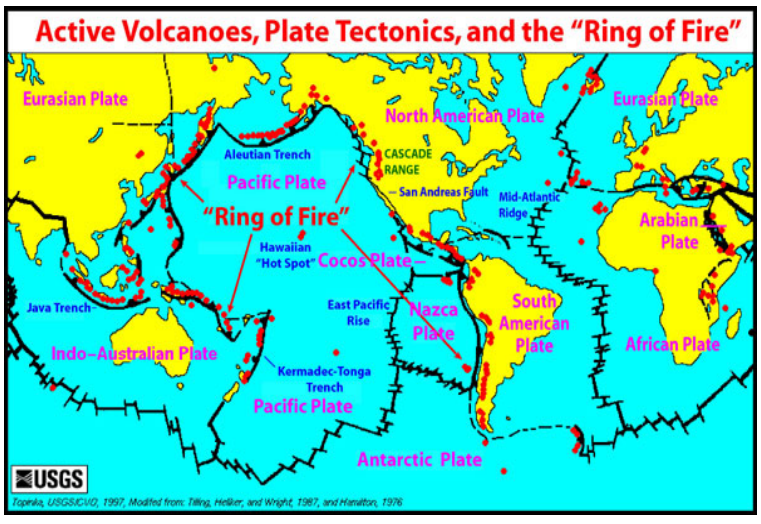
A volcano which has steep volcanic cone that is built up by dense lava flows and pyroclastic debris. Also called a stratovolcano

Repose.

The time lag between the Volcanic eruptions is called repose.

Pacific Ring of Fire

Pacific Ring of Fire is a horse shoe shaped 40,000 kilometer area with 75% of Earth's active and dormant volcanoes. It is the area with large number of Volcanic Eruptions and Earth quakes (90%). The most active Volcanoes are located in Chile, Mexico, United States, Canada, Russian Far East, Japan, Philippines, Indonesia, New Zealand, & Antarctica. The most important Volcanoes of the Pacific Ring of Fire are shown in the graphics:



List of Recently Active Volcanoes and their Location

In Examinations, most questions related to volcanoes are related to their location and recent activity. The following list presents you the names of the volcanoes which were recently active and caused damages/ made some news. The location is important so I have take help of Google maps to indicate the location of the volcanoes. Shows the location of the volcano.

Mount Etna

Country : Italy

Last Activity : 2010

Mount Etna is located near Catania, Sicily's second largest city, has one of the world's longest documented records of historical volcanism, dating back to 1500 BC.

Nyamuragira

Location : Congo

Last Activity : 2010

Nyamuragira is Africa's most active volcano, located 25 km north of Lake Kivu.

Ulawun, Volcano

Country: Papua New Guinea

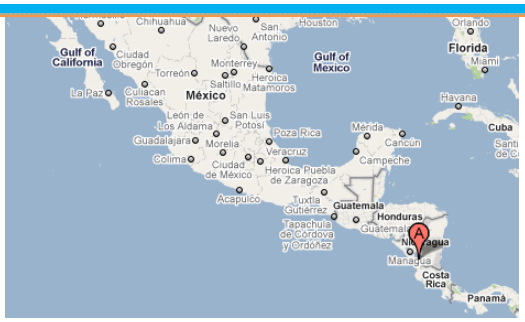
Last Known Eruption: 2010

Ulawun volcano, also known as the Father, rises above the north coast of the island of New Britain across a low saddle NE of Bamus volcano, the South Son.

Kirishima

Country: Japan

Last Known Eruption: 2010

Concepción **Country: Nicaragua** **Last Known Eruption: 2010** **Volcáno Concepción is one of Nicaragua's highest and most active volcanoes.**	
Poás & Turrialba **Country: Costa Rica** **Last Known Eruption: 2010** **Poás & Turrialba are the most active volcanoes of Costa Rica.**	
Tungurahua **Country: Ecuador** **Last Known Eruption: 2010** **Tungurahua is one of Ecuador's most active volcanoes.**	
Eyjafjallajökull **Country: Iceland** **Last Known Eruption: 2010** Eyjafjallajökull (also known as Eyjafjöll) is located west of Katla volcano. It is an elongated subglacial stratovolcano with a 2.5-km-wide summit caldera. The last historical eruption of Eyjafjallajökull prior to an eruption in 2010 produced intermediate-to-silicic tephra from the central caldera during December 1821 to January 1823. The latest eruption occured in April 2010 which led to air travel disruption in northwest Europe for six days from 15 April and in May 2010, including the closure of airspace over many parts of Europe. On 23 May 2010, the London Volcanic Ash Advisory Commission declared the eruption to have stopped, but are continuing to monitor the volcano.	

Volcanic Explosivity Index

Volcanic Explosivity Index was devised by Chris Newhall & Stephan Self. This scale used Volume of Volcanic Products, Height of Plume and other observations. Highest Magnitude is 8. A Volcano with 8 VEI can eject 1012 Cubic meters of Tephra. As per this index Ultra-Plinian are the Highest Volcanoes with VEI of 8. Example is Oruanui eruption of New Zealand which happened 70,000 years ago. Others are as follows:

	Ejecta volume	Classification	Plume	Example
	< 10,000 m³	Hawaiian	< 100 m	Mauna Loa, Hawaai
	> 10,000 m³	Hawaiian/Strombolian	100-1000 m	Stromboli, Italy
	> 1,000,000 m³	Strombolian/Vulcanian	1-5 km	Galeras (1993), Colombia
	> 10,000,000 m³	Vulcanian/Peléan	3-15 km	Cordón Caulle (1921), Chile
	> 0.1 km³	Peléan/Plinian	10-25 km	Eyjafjallajökull (2010), Iceland
	> 1 km³	Plinian	> 25 km	Mount St. Helens (1980), United States
	> 10 km³	Plinian/Ultra-Plinian	> 25 km	Krakatoa (1883), Indonesia
	> 100 km³	Plinian/Ultra-Plinian	> 25 km	Tambora (1815), Indonesia
	> 1,000 km³	Ultra-Plinian	> 25 km	Taupo (70000 YA), New Zealand

Please note that Mauna Loa at Hawaiian Islands is the largest Volcano on earth both in terms of volume and area covered. It is an active shield Volcano with a volume of 75000 square kilometers. Its most recent eruption occurred in 1984.

Notes

- There are more than 1500 active Volcanoes in the word.
- Crater Lake in Oregaon USA was formed when a Volcano lost its top in eruption thousands of years ago.
- The Volcanic Ash is mostly acidic.
- The Olympus Mons is the tallest known Volcano on Planet Mars.
- Italy's Stromboli Volcano is erupting for more than 2500 years.
- The Mount St. Helense had erupted in 1980, which caused the ash travel across entire US.
- The 1883 eruption of Indonesia's Krakota eruption was so loud that blasts were heared 3000 miles away.
- Mauna Kea in Hawaii is the tallest Volcano on earth. The meaning of its name is White Mountain as it is snow capped. Its height is 4205 meter from Sea Level, however, if it measured from its oceanic base, it is the higher than mount Everest (over 10000 meters).

Basics of Rocks

We know that naturally occurring solid chemical substances, which were formed through geological processes, have characteristic chemical composition along with a highly ordered atomic structure, and some specific physical properties are known as minerals.

The Great Oxygenation Event or oxygen catastrophe which happened 2400 million years ago in the Proterozoic eon triggered an explosive growth in the diversity of minerals on Earth.

We know that *Lithos* is a Greek term which means a stone. **Lithography** is writing inscriptions / printing on stones. Science that treats of rocks, as regards their mineral constitution and classification, and their mode of occurrence in nature is **Lithology**. Earth's outermost solid layer, which is made of rocks, is called **Lithosphere.**

Lithology v/s Petrology

Petrology is the scientific study of the Rocks. Lithology is now a subdivision of petrology and Lithology deals with the macroscopic description of the rocks. Petrology exhaustively uses the Mineralology, Optical Mineralogy and Petrography and goes to the level of microscopic details.

Rocks essentially contain minerals. The aggregate of two or more minerals that form the considerable part of the Lithosphere is a **Rock.**

Magma

Magma is a complex high-temperature fluid substance.

Magma contains the following:

a. Liquid Rocks only
b. Both Liquid and Solid Rocks
c. Liquid Rocks, Solid Rocks and Gas
d. Liquid Rocks and Gas

Magma is a mixture of molten rocks, volatiles (gas) and other solids. It originated from the partial melting of the lower crust and the upper mantle, mainly at depths of 15-200 kilometers. Most magma is as hot as 700 °C to 1300 °C and is silicate mixtures mostly.

The chambers where Magma collects are called magma chambers. The magma chambers feed a volcano.

Large mass of intrusive igneous rocks, which are believed to have solidified deep within the earth, from the Magma are called plutons. "Plutons" word has its root in the Pluto and the theory is called "*Plutonism*". This is one of the process by which Magma solidifies and cools. Another process is Volcanic Eruption. Bulks of the igneous rocks are result of the cooling and solidifying of Magma.

There are two known processes by which magma ceases to exist, by volcanic eruption or by Plutonism.

In both cases the bulk of the magma eventually cools and form igneous rocks. The consequence of creation of magma, its migration from the site of partial melting into an area of lower stress , generally a cooler volume of the crust, are some of the processes by which magmas undergo bulk chemical change during the partial melting process, cooling, emplacement or eruption and the collective term used for this is Igneous differentiation.

Accordingly, there are several different types of magma viz. Ultramafic (picritic), Mafic (basaltic), Intermediate (andesitic) and Felsic (rhyolitic).

- **Ultramafic (picritic):** Also known as silicic magma. Relatively cooler and highly viscous.
- **Mafic (basaltic):** Very hot, beyond the 900 °C. Basalt is a volcanic Rock that forms from mafic Magma.
- **Intermediate (andesitic):** Basaltic magma may also mix with rhyolitic magma, it is intermediate or andesitic magma. The Andes mountains made up of these rocks.
- **Felsic (rhyolitic):** This is enriched in the lighter elements such as silicon, oxygen, aluminium, sodium, and potassium and called Felsic because of feldspar and Silica.

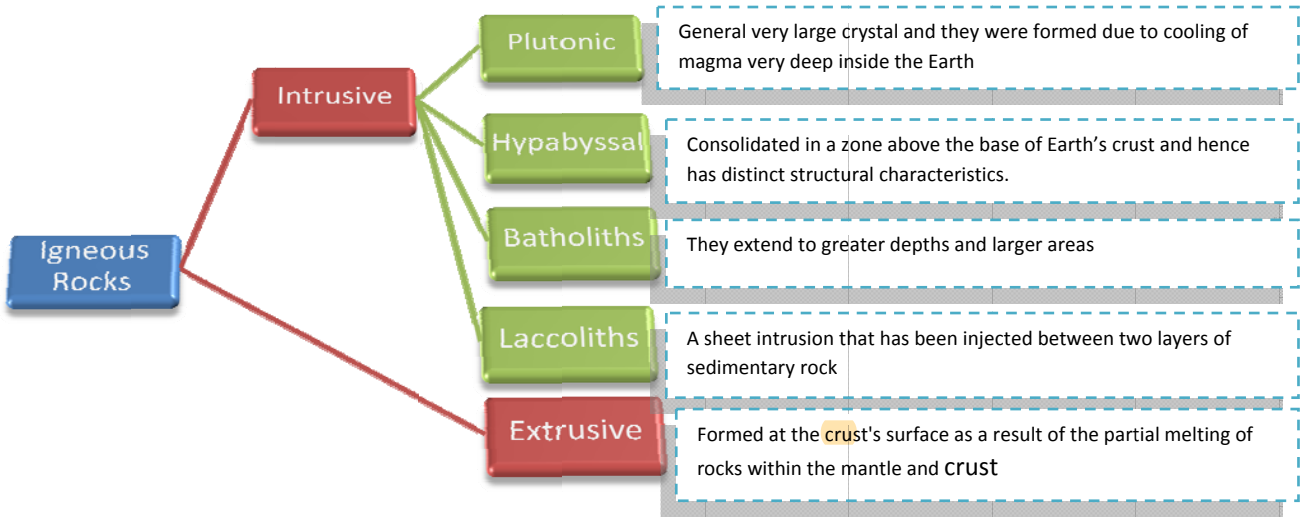
Types of Rocks

The three types of Rocks are Sedimentary, Igneous and Metamorphic.

- **Igneous rocks**: These rocks have crystallized from magma which is made up of various components of pre-existing rocks and has been subjected to melting either at subduction zones or within the Earth's mantle.
- **Sedimentary rocks:** These rocks are formed through the gradual accumulation of sediment, such as sand on a beach or mud on a river bed. The sediment is buried and then it is compacted as more and more material is deposited on top. In several thousand to Lakhs of years , the sediment becomes so dense that it becomes a rock. This process is known as lithification.
- **Metamorphic rocks** : These rocks once existed as igneous or sedimentary rocks but have been subjected to varying degrees of pressure and heat within the Earth's crust. The processes involved changes the composition and fabric of the rock and their original nature is often hard to distinguish. Metamorphic rocks are typically found in areas of mountain building.

Igneous Rocks

The upper 16 kilometers of the Earth's crust is made up of 95% Igneous rock, with a thin covering of sedimentary and metamorphic rocks. The igneous rocks are generally hard and water percolates in them not so easily. Following graphic shows the types of Igneous Rocks:

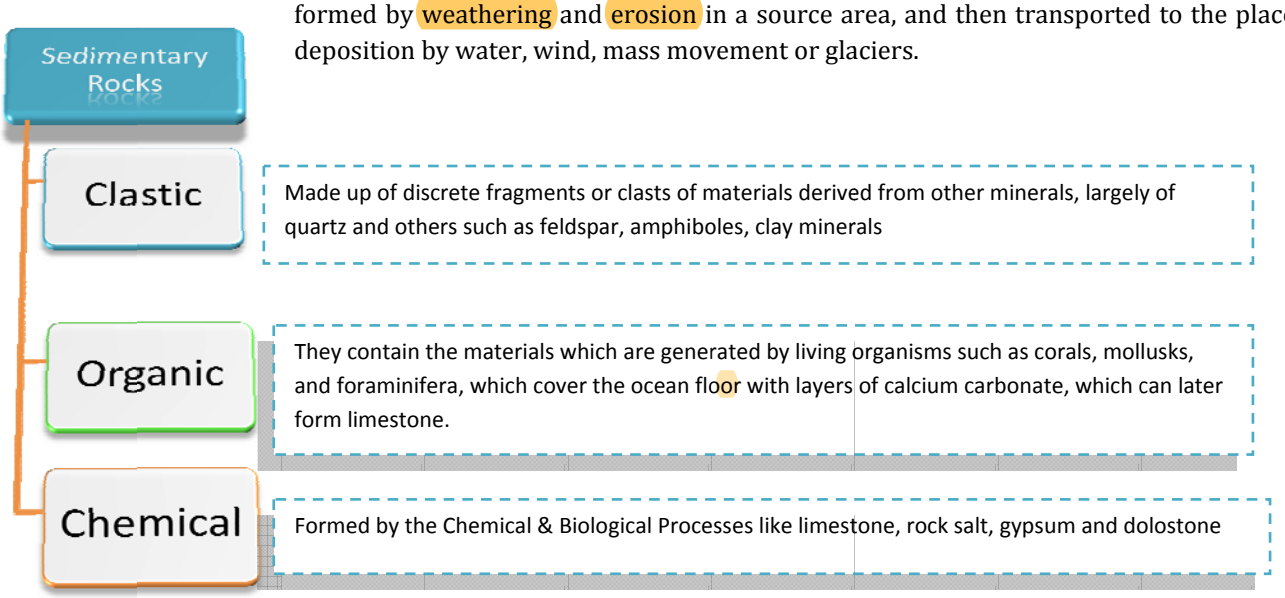


Examples of Igneous Rocks

☑ **Granite:** Intrusive, Felsic, igneous rock. Worldwide average chemical composition of Igneous Rocks has SiO2 — 72.04% & Al2O3 — 14.42%
☑ **Diorite:** intermediate intrusive igneous rock
☑ **Gabbro:** Mafic igneous rocks equivalent to basalt.
☑ **Peridotite**
☑ **Rhyolite**
☑ **Andesite**
☑ **Basalt**
☑ **Komatiite**
☑ **Diabase**

Sedimentary Rocks

They are formed from the compaction, cementation and hardening of sediments derived from former rocks. These rocks are formed on the earth's surface by the hydrological system by processes that cause mineral and organic detritus to settle. The sediment is formed by weathering and erosion in a source area, and then transported to the place of deposition by water, wind, mass movement or glaciers.



Metamorphic Rocks

These are the rocks formed from the preexisting rocks within the Earth's crust by changes in temperature and pressure and by chemical action of fluid. This means that Both the Igneous and Sedimentary socks undergo profound physical and chemical changes under the increased pressure and temperature.

The process is called "metamorphism". These Rocks are formed simply by being deep beneath the Earth's surface, subjected to high temperatures and the great pressure of the rock layers above it. Some examples are gneiss, slate, marble, schist, and quartzite. The layering is called foliation.

Some metamorphic Rocks are Schist, Gneiss, Slate, Quartzite, Marble, Granite, Gypsum.

WEATHERING

Denudation

There are two types of the processes that affect the landforms viz. Exogenic and Endogenic. Endogenic are the processes that occur within the earth's surface such as Plate tectonics, earthquakes, volcanoes etc. The tidal force is Exogenic. The radiation from Sun is also Exogenic.

Further, there are 3 Exogenic geological processes which refer to the process of disaggregation which lead to the reduction in the elevation & relief of the landforms and landscapes such as rocks and mountains. These 3 important phenomena are weathering, mass wasting and erosion. These all together are called "Degradation" "Denudation".

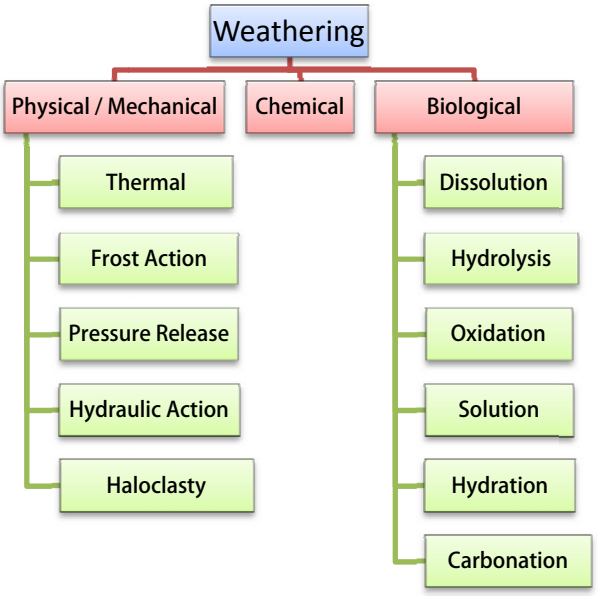
Endogenic processes uplift and expose continental crust to the Exogenic denudation. Exogenic denudation works in opposition and reduces landscapes to sea level.

Weathering is the breaking down of Rocks, soils and minerals through "direct Contact" with the atmosphere of the earth. It occurs *in situ*, means there is **no movement** involved.

- This is distinct from **erosion** which involves the movement of rocks and minerals such as water, ice, wind and gravity.
- **Mass wasting** involves the movement of the rocks and particles across a slope **due to gravity.**

Types of Weathering

Weathering is the *in situ* disintegration and breakdown of rocks, soils and minerals. It is of three types Mechanical or Physical Weathering, Chemical Weathering & Biological Weathering.



Physical Weathering:

A. Thermal Changes: Repeated changes in the temperature (heating and cooling) exert the stress on the outer layers of the rocks which is called as Thermal Stress.

The rocks expand when there is a rise in the temperature and contract when there is a fall in the temperature. In deserts, the phenomena are more common as there is large diurnal temperature range. The Forest fires can raise the temperature suddenly and this leads to **thermal shock**.

Thermal Shock and Thermal Fatigue

As we know that some objects such as Glass & ceramics crack whenever there is a sudden change of temperature. This is because of their **high thermal expansion coefficients.** Where the different parts of the object expand different amounts this causes a strain, which is also known as Thermal Shock. Another concept is thermal fatigue which refers to structural damage to a material which is exposed to cyclic stresses.

Q. 1: Consider the following statements:

1. The volume of all materials changes with changes in temperature
2. The volume of all materials increases when temperature increased and decreases when temperature is decreased.

In the above question, statement 2 is incorrect. It is true that all materials respond by changing volumes because of temperature. Most materials expand when there is a rise in temperature. But there are some rare example which contract when temperature increases and expand when temperature decreases. This is called Thermal contraction.

The coefficient of thermal expansion is positive for the material which expand when there is a rise in temperature. If the coefficient of thermal expansion becomes zero, there is no expansion or contraction. At negative coefficient, the material contracts when there is a rise in temperature. Best example is water. Water

when cooled till 4°C, the coefficient of thermal expansion decreases and become zero at 4°C. After that, when temperature is further reduced, it expands. So, at 4°C, water has maximum density. After that, density is reduced and this is the reason why ice floats and the water bodies are able to retain a temperature of 4°C at sub zero weathers.

Similarly, **Pure Silicon** has a negative coefficient of thermal expansion between -255°C to -153°C.

B. Frost Action: We know that ice has a lesser density than water. This means that when water freezes, its volume increases. The water within the cracks of the rocks, when freezes exerts pressure on the rocks because of expansion. This strain may lead to breaking off of the fragments. Ice is frost so this action is called frost action. Repeated freezing and melting causes shattering of the rocks. The examples are mountains peaks & glaciers.

C. Pressure Release or exfoliation: This refers to the release of the pressure from unloading of existing rock on the rocks that lie beneath it due to other processes such as erosion. The igneous rocks are formed deep in earth and when the rocks above them get removed, the igneous rocks expose and the pressure is released. This causes their outermost surfaces to expand. This expansion leads to weathering.

D. Hydraulic Action: This phenomenon takes place due to very high powered water waves. When water rushes into cracks in the rocks with a very fast speed, the trap of air in the cracks get compressed and thus weakens the rocks. When water retreats, the trapped air is suddenly released with explosive force.

E. **Salt Crystallization or Haloclasty:** This refers to the process in which the rocks are denudated due to salt formation. This is a two step process. The first step is started when saline water seeps into cracks and evaporates depositing salt crystals. In the second step, when the rocks are heated up, the crystals expand putting pressure on the surrounding rock. Over the period of time, it splinters the stone into fragments.

Q. 2 In which of the following types of climates, **Haloclasty** is most common?

A. Arid
B. Mediterranean
C. Arctic
D. Humid Continental

Answer of the above question is: **Arid Climates**. This is because, Arid climates have strong evaporation and thus salt crystallization is most common in those areas.

Biological Weathering:

Biological Weathering refers to the contribution made by the organisms such as Lichens and mosses, which grow on essentially bare rock surfaces and create a more humid chemical microenvironment. Biological weathering is both physical as well as chemical breakdown of the surface micro layer of the rock. The animals such as earthworms and other annelids, moles, rabbits all contribute to the biological weathering.

Chemical Weathering:

Chemical weathering refers to the changes in the chemical composition of the rocks and generally refers to the chemical reactions of water with minerals.

A. Hydration: Hydration means absorption of water by some kinds of rock, leading to expansions and disintegrations. When water molecules bind with the mineral molecules, it is called Mineral Hydration.

B. **Hydrolysis:** The chemical breakdown of the rocks caused by rainwater is called Hydrolysis. The result may be secondary minerals with different chemical structure.

C. **Oxidation:** Oxidation or rusting occurs when atmospheric oxygen reacts with the minerals such as Iron Ores. This leads to decomposition of the rocks.
D. **Solutions:** This refers to dissolving of the minerals in water.
E. **Carbonation:** carbonation refers to the chemical weathering in which Carbon dioxide attacks the rocks after it makes weak acid reacting the water. The rocks are generally made up of calcium carbonate such as Limestone and Chalk. The degradation

Mass wasting:

In Mass Wasting, the gravitational force of the earth acts directly on the loose material and the unstable slopes result the slide of the rocks and rock debris. This is known as Mass movement. This movement may be slow or fast depending upon the slope angle. The steepest angle that a cohesion less slope can maintain without losing its stability is known as its **Critical angle of repose**

Mass wasting is of following types:

A. **Creeps:** Its a long term process which refers to the small movements of soil or rock in different directions over time, directed by gravity. The speed is so slow that naked eye is not able to show the movement.
B. **Landslides:** It includes the rock slides, slumps (short distance moving of rocks) & sturzstroms (more horizontal movement when compared to its initial vertical drop). Landslides are most common type of mass wasting.
C. **Flows:** Flows refer to the movement of the soil, dust, rock particles and bigger pabbles resembling the fluid behavior. Examples of the flows are avalanches, mudflows, debris flows, earth flow, lahars and sturzstroms. The water and air may contribute to the fluid like behavior.
D. **Topples:** When rocks break away and fall from a slope , it is called Topples.
E. **Slump:** Slump refers to slipping of the rock material.
F. **Falls:** Rocks fell from the steep slopes such as a cliff face, and the movement may be contributed by the earthquakes, rain, plant-root wedging, expanding ice, among other things.

Erosion:

Erosions refer to the earth-sculpting processes in which the debris produced by weathering is "transported". So it's a kind of weathering in which the soils break up and get carried away. The agents of erosion are Rainwater, River water, ice, wind, sea waves, and underground water.

Erosion is a very important topic physical and well as human geography. Apart from the transport by wind, water, or ice; erosion also involves the down-slope creep of soil and erosion by the living organisms, such as burrowing animals, in the case of bioerosion, and human land use.

MEGARELIEF

On a large scale, the landscapes of can be divided into three orders of relief called Megarelief. These classify landscapes by scale, from enormous ocean basins and continents down to local hills, spurs, cliffs, valleys, gorges and river terraces. Here is an introduction:

First Order of Relief:

The broadest category of land forms includes huge continental platforms and ocean basins. Continental platforms are the masses of crust that exist above or near sea level, including the undersea continental shelves along the coastline. The ocean basins are entirely below the sea level. ApproXimately 71 percent of the earth is covered by water, with only about 29 percent of its surface appearing as continents and islands.

The distribution of land and water in evidence today demonstrates a distinct water hemisphere and continental hemisphere.

Second Order of Relief:

Continental features that are classified in the second order of relief include continental masses, mountain masses, plateaus, plains and lowlands. A few examples are the Himalayas, Alps, Rocky Mountains, Andes, Tibetan plateau, plateau of Anatolia (Turkey), Indo-Gangetic plains, Siberian lowlands and the plains of Mississippi. The great rockcores (shields) that form the heart of each continental mass arc of this order. In the ocean basins. the second order of relief includes continental rises, slopes, abyssal plains, mid-ocean ridges, submarine canyons, and subduction trenchcs.

Third Order of Relief:

The third order of relief includes individual peaks, cliffs, valleys, hills, spurs, gorges, sand dunes, caves, moraines, cirques, ripples, beaches, etc. These features are identified as local landscapes.

Geosyncline

Geosyncline is a major structural down fold in the earth's crust on a sub-continental scale. It comprises a linear basin which serves as a repository for considerable thickness of sediments derived from land masses. The increasing sedimentation causes progressive subsidence of the geosynclinal floor prior to strong deformation of the sediments. After great thickness of sediment had built up, horizontal forces from the seaward side of geosyncline began to squeeze the sediments, shortening and thickening the crust, producing a high-standing mountain system, while simultaneously pushing much of the sediments deeper into the earth. It was believed that the melting of these deeply buried sediments generated magma which moved upward, intruding the overlying sediments. Thus, a complex mountain chain, containing folded and faulted sedimentary rocks surrounding a core of igneous intrusions and metamorphic rocks was formed.

Types of Mountains

A mountain may have several forms. Important among them are: i) mountain ridge, ii) mountain range, iii) mountain chain, iv) mountain system, v) mountain group, and vi) cordillera.

Mountain Ridge:

It is a linear, steep-sided high hill, or spur. The slope of one side of a ridge is steep, while the other side is of moderate slope. A ridge, however, may have symmetrical slopes on both sides. The Shimla Ridge is a good example of mountain ridge.

Mountain Range:

A mountain range is a linear system of mountains and hills having several ridges, peaks, summits and valleys.

Mountain Chain:

A mountain chain consists of several parallel long and narrow mountains of different periods.

Mountain System:

A mountain system consists of different mountain ranges of the same period. In a mountain system, different mountain ranges are separated by valleys.

Mountain Group:

A mountain group consists of several unsystematic patterns of different mountain systems.

Cordillera:

It is a Spanish term referring to a system or major group of mountains. A cordillera consists of several mountain groups and systems. In other words, cordillera is a community of mountains having different ridges, ranges, mountain chains and mountain systems. It usually refers to an orogenic belt at a continental scale, e.g., the Western Cordillera of the U.S.A., which includes all the ranges between the Pacific and the Great Plains.

Mountain Kinds

No two mountains are the same. They, however, can be classified on the basis of their most dominant characteristics into: i) folded mountains, ii) volcanic mountains, iii) fault-block mountains, and iv) upwarped (dome) mountains.

Folded Mountains

Folded mountains comprise the largest and most complex mountain systems. Although folding is the dominant characteristic, faulting and igneous activity are always present in varying degrees in folded mountains. The Alps, Himalayas, Rockies, Andes, Appalachians, Tien Shan, Caucasus, Elburz, Hindukush, etc., are all of this type. The folded mountains present the world's major mountain systems. They are the youngest mountains in the world.

Volcanic Mountains:

Volcanic mountains are formed from the extrusion of Java and pyroclastic materials, which if continued long enough, produces gigantic volcanic piles. The Kilimanjaro (Africa), Cotopaxi (Andes), Mt. Rainier, Hood and Shasta (U.S.A.), are some of the examples of volcanic mountains

Fault Block Mountains:

Fault-block Mountains are bounded by high angle normal faults. Some of them are associated with rift valleys such as those in East Africa, while others appear to be formed by vertical uplifting. A notable example of fault-block mountain is found in the Basin and Range Province of the southwestern USA. The Salt Range of Pakistan, and Siena-Nevada of California (U.S.A.) are also the typical examples of fault-block mountains.

Upwarped (Domed) Mountains

Upwarped or domed mountains are formed by magmatic intrusions and upwarping of the crystal surface. The lava domes, batholithic domes, laccolithic domes, salt domes, etc., are the examples of dome mountains. The Black Hills of South Dakota, and the Adirondack mountains of New York may be cited as the examples of upwarped (domes) mountains.

Mountain Kinds on Orogeny Basis

Mountains can also be divided on the basis of their making i.e. Orogeny during different geological periods.

Pre-Cambrian Orogeny:

This was the first ever Orogeny on earth and represents the oldest mountains of the earth. The examples are Laurasian of North America, Elogoman etc.

Caledonian or Mid Paleozoic Orogeny

It occurred during Silurian and Devonian periods. The example are Aravallis of India, Brazilian Highlands in America, Scotland of Europe etc.

Harcynian or Late Paleozoic Orogeny

This occurred in the Permian period. Example are Appalachian of North America, Black Forest of Europe etc.

Alpine Orogeny

This took place in Tertiary period and represents the youngest and newest mountain ranges of Earth. The example are Himalaya, Rocky, Andes, Apennines, Alps etc.

Plateaus

Plateau is an elevated tract of relatively flat land, usually limited on at least one side by a steep slope falling abruptly to lower land. It may also be delimited in places by abrupt slopes rising to residual mountains or mountain ranges, as in the Tibetan plateau, where it occurs as an intermontane plateau. The term is also used to refer to a structural surface such as Meseta of Spain, in which case it is a tectonic plateau. It is also used to describe extensive lava flows (lava plateau). The surfaces of plateaus may be plain-like in quality, very flat, rolling or hilly, or they may be so dissected by streams and glaciers that it is difficult to recognize their original plateau characteristics.

Diastrophic Plateaus:

Diastrophism is the large-scale deformation of the earth's crust which produces continents, ocean basins and mountain ranges, etc. All the highest plateaus of the earth are the direct products of diastrophism. Since their uplifts they have been modified by various agents of erosion and in many cases by volcanism and minor earth movements. For convenience they may be classified as:

1. Intermontane plateaus
2. Mountain border plateaus
3. Domed plateaus,
4. Volcanic plateaus
5. Erosional plateaus.

Intermontane Plateau:

Intermontane Plateaus include the highest, largest and in many respects most complex plateaus of the world. Their surfaces show an extraordinary variety of topographic features.

- The best example is the Tibetan Plateau. It stretches approximately 1,000 kilometers north to south and 2,500 kilometers east to west. The average elevation is over 4,500 meters (14,800 ft), and all 14 of the world's 8,000 metres (26,000 ft) and higher peaks are found in the region. Sometimes called "the roof of the world," it is the highest and biggest plateau, with an area of 2.5 million sq. km or about four times the size of France. The Tibetan Plateau is bounded on the north by the Kunlun mountains, and in the south by the mighty Himalayas. These two systems meet to make the western boundary of the plateau, while on the east is the less sharp demarcation between the plateau proper and the lower mountains of western China.The Qinghai-Tibet Plateau not only gives rise to most of Asia's major rivers, it also holds a constellation of salt- and freshwater lakes.
- Another example of Intermontane Plateau is Plateau of Bolivia and Peru. It lies largely in Bolivia at an average elevation of more than 3,692 metres (12,000 ft) above the sea level.
- One more example is Mexican Plateau which extends from the United States border in the north to the Cordillera Neovolcánica in the south, and is bounded by the Sierra Madre Occidental and Sierra Madre Oriental to the west and east, respectively.

Border Plateaus

Many plateaus border mountain ranges and owe their present position to the same uplifts that raised the mountains. Piedmont plateau is an excellent example of border plateaus. This plateau is a strip of land that

stands between tile Atlantic coastal plains and the Appalachian Mountains. Its eastern side is marked by a more or less definite fall-line where the gradient of the rivers is steepest. On the west it terminates against the mountains of the Blue Ridge. Plateau of Colorado is also an example of the border plateau. It is bounded on the northeast by the Rocky Mountains and on the southwest by the Basin and Range Province.

Domed Plateaus:

The plateau of Ozark (U.S.A.) is a good example of domed plateau. Ozark plateau was uplifted by folding and faulting into a broad dome some 65,000 sq km (40,000 square miles) in area during the Appalachian Revolution which occurred at the close of the Paleozoic Era.

Volcanic Plateaus

Volcanoes also form several varieties of plateaus. The largest are built by the lava flow. Smaller, degraded plateaus are formed by the resistant lava caps that protect the land from erosion and maintain its high elevation after the surrounding land has been worn away.

Erosional Plateaus

Such plateaus are formed particularly in semiarid regions where streams have cut away portions of high lands.

Land Forms

Landforms are defined as the geomorphologic units defined by its surface form and location in the landscape. Landforms are typical elements of the topography. The water body interfaces also called landforms. They are categorized on the basis of elevation, slope, orientation, stratification, rock exposure, and soil types as follows:

1. Aeolian landforms
2. Coastal and oceanic landforms
3. Erosion landforms
4. Fluvial landforms
5. Mountain and glacial landforms
6. Slope landforms
7. Volcanic landforms

Aeolian landforms

Aeolian landforms refer to the Landforms that are formed by the winds.

Difference between Deflation and Abrasion: Wind erodes the Earth's surface by removal of loose, fine-grained particles by turbulent eddy actions and it is called **Deflation.** Regions which experience intense and sustained erosion are called **deflation zones. Abrasion** refers to grinding of the rock surfaces with particles captured in the air.

Aeolian Landforms: Erosional

Zeugen or Rock Mushrooms :

They are also known as rock pedestal or a pedestal rock or Zeugen. Usually Found in Desert Areas.

Yardangs

Yardangs form in environments where water is scarce and the prevailing winds are strong, unidirectional and carry an abrasive sediment load. They consist of an elongated ridge carved by the unidirections erosion.

Dreikanter

Dreikanter exhibits a 3 faced Pyramidal Shape. They typically form in Deserts due to wind erosion.

Blow Outs

Blowouts refer to sandy depressions in a sand dune ecosystem, which are caused by the removal of sediments by wind.

Inselbergs

Inselbergs refer to the prominent steep sided hill of solid rock rising abruptly from a plain of low relief. Inselbergs are generally composed of resistant rocks such as Granites.

Desert pavement

Desert pavement refers to mountain wash containing pebbles, gravels and sand particles exposed to wind and surface appears as a pavement with closely packed, interlocking angular or rounded rock fragments of pebble and cobble size

Aeolian Landforms: Depositional

Erg or Sand Sea :

Erg is a sand sea or a dune sea. They are flat area of desert covered with wind-swept sand with little or no vegetative cover. The area is generally more than 100 square miles and is deposited by windblown sand. Largest Hot Desert in the World viz. Sahara has several sand Seas. The Ergs have 85% of Earth's mobile sand.

Ripples:

Ripples are well marked small waves produced on the surface of sand, mud and even rock by the drag of the wind / water moving over it. They are most common in deserts.

Barchan:

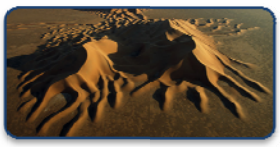
Barchan refers to crescent shaped dunes, which have tips or horns pointing downwards. Barchans are found in desert areas which have low sand quantity.

Longitudinal dunes

Longitudinal dunes are also known as Seif dunes. Seif is a arabic word for Sword. These are long, slightly sinuous, ridge shapped dunes which are parellel to the wind direction, elongate parallel to the prevailing wind, possibly caused by a larger dune having its smaller sides blown away. Seif dunes are sharp-crested and are common in the Sahara.

Transverse Dunes:

Transverse Dunes are asymmatrical sands in deserts which are at right angle to the wind direction. They are most probably caused by a steady build-up of sand on an already existing minuscule mound.



Star Dunes:

Star Dunes are giant star shapped dunes with 3 or more sinuous arms extending outwards from the center. These shapes can alter due to windspeeds.

World's Largest Hot Deserts

Desert's Name	Type	Image	Area	Location Countries
Sahara	Subtropical		91 Lakh Km ²	Algeria, Chad, Egypt, Libya, Mali, Niger, Mauritania, Morocco, Sudan and Tunisia
Arabian Desert	Subtropical		23.30 Lakh Km²	Saudi Arabia, Jordan, Iraq, Kuwait, Qatar, United Arab Emirates, Oman and Yemen
Gobi Desert	Cold Winter		13 Lakh km²	Mongolia and China

Kalahari Desert	Subtropical		9 Lakh Km²	Angola, Botswana, Namibia and South Africa
Patagonian Desert	Cold Winter		6.70 Lakh Km²	Argentina and Chile
Great Victoria Desert	Subtropical		6.47 Lakh Km²	Australia
Syrian Desert	Subtropical		5.20 Lakh Km²	Syria, Jordan and Iraq
Chihuahuan Desert	Subtropical		4.5 Lakh Km²	Mexico and United States
Great Sandy Desert	Subtropical		4.00 Lakh Km²	Australia
Thar Desert	Subtropical		2.00 Lakh Km ²	India and Pakistan
Gibson Desert	Subtropical		1.5 Lakh Km ²	Australia

Simpson Desert	Subtropical		1.45 Lakh Km ²	Australia
Atacama Desert	Cool Coastal		1.40 Lakh Km ²	Chile and Peru
Namib Desert	Cool Coastal		81,000 Lakh Km ²	Namibia and Angola
Mojave Desert	Subtropical		65000 Km ²	United States

Fluvial Landscapes

The landforms which develop as a result of the water action are known as Fluvial Landforms. Running water such as rivers are the most important agent of erosion, as we know. Other agents such as Glaciers, Groundwater, wind and sea water are locally dominant agents of erosion. The Fluvial processes are most important of all the exogeneric processes as landforms associated with them have overall dominance in the environment of terrestrial life. These fluvial processes can be divided into three phases viz. **erosion, transportation and deposition**.

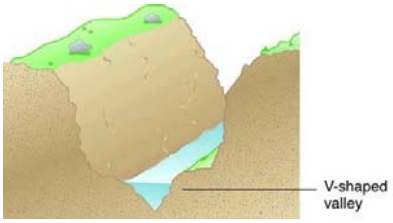
Erosion

The **Erosion** can be **normal erosion** which takes place by the natural physical processes or the **Accelerated Erosion**, which is produced by human interference. The **Sheet Erosion** refers to the **s**urface flow removing soil in thin layers. It can be acccelelerated in the Steep slopes, where innumerable closely spaced channels are formed, which grows larger form in gullies (steep-walled canyon like trench). The Erosion can be of following types:

1. Chemical erosion: Corrosion (Or solution) and carbonation.

2. Mechanical erosion.
3. Impaction (effect of blow upon the river bed or banks by large boulders).
4. Cavitations (shattering and breaking up of the stream load through collisions and mutual abrasion).
5. Hydraulic action (lifting and quarrying effect of rushing water).
6. Corrosion or abrasion (stream uses its load to scrape away its bed, particularly in steep confined sections of stream channels).

Landforms made by River Erosion



V-shaped Valley: Valley starts as small and narrow rills which gradually develop into long and wide gullies. The gullies will further deeper widen and lengthen to give rise to valleys which is V-shaped. The **River valley** is an important erosional landform. They are formed in the youthful stage of fluvial cycle of erosion. The vertical erosion or valley deepening causes the V-shaped valleys.

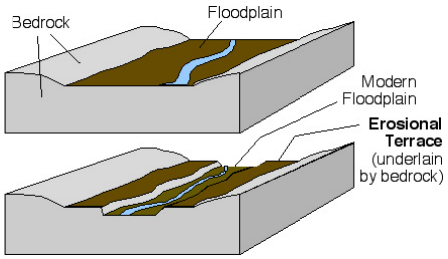
Gorge & Canyons:

The V-shaped valley can be a **Gorge**, where steep precipitous wall within which a narrow river is confined (e.g. – Indus, Sutlej, Brahmaputra, Rhine, Zambezi). Thus, we can say that Gorge is a V-shaped valley but its sides becomes so steep that they look almost vertical. Or it can be a **Canyon**, which is basically a very deep and extended gorge. The Grand Canyon in Arizona, United States of America is the largest Canyon in the world.

Meander:

The meanders or meandering rivers are the low slope rivers which are not choked with the sediment and move back and forth in a zig-zag order of loops. The meander has thus a serpentine path and it helps in accommodating in extra volume of water.

River Terraces



River terraces are abandoned floodplains that formed when a river flowed at a higher level than it does today. Thus, these are the surfaces that mark an old valley floor or floodplain levels.

Peneplain

When an extensive area has been eroded sufficiently to give the look of almost a plain, it is called a Peneplain.

Landforms made by River Deposition

Alluvial Fans

Natural leaves

When the velocity of the running water, as it comes out of hills and meets the plain, decreases, it dumps the transported material at the foothills. The sttrucutre made are called alluvial fans. The alluvial fans are formed due to accumulation of materials in the form of fan and cones respectively at the base of foot hills Alluvial cones are made of coarse materials than the alluvial fans.

Narrow belt of ridges of low height built by the deposition of sediments by the spill water of the stream on its either bank.

Food plain

Surfaces on either side of a stream that is frequently inundated.

Crevasse splays

Formed by breaching of leaves when water escapes through a series of distributaries channels.

Back swamps

Plain area adjoining a levee may contain marshes called back swamps.

Yazoo streams

Distributions of rivers occupying lateral positions.

Delta

Delta is the triangular deposition at the mouth of a river debouching in a lake or a sea. The Factors that help in delta formation are as follows:

1. Long courses of rivers.
2. Medium size sediments.
3. Calm or sheltered sea.
4. Suitable place (shallow sea and lake shores).
5. Large amount of sediments.
6. Accelerated erosion.
7. Stable condition of sea coast.

- On the basis of shape delta can be divided into following categories :

1. Arcuate
2. Bird-foot
3. Estuarine
4. Truncated

Arcuate (lobate form) Delta:

The Arcuate delta resembles the fan and is convex towards the Sea. It is semicircular in shape and is commonly found in semi-arid region; growing delta such as Nile, Niger, Ganga, Indus, Mekong, Irrawaddy, Rhine, Volga, Danube, Rhone, Lena rivers.

Bird-foot Delta

Birdfoot Delta is also known as a finger delta. In these deltas, the sediments deposited are composed of those fine particles which are received from the limestone rocks. The rivers with high velocity carry suspended finer load to greater distance inside the oceanic water (such as Mississippi).

Estuarine delta

When a river enters the sea through the single mouth or estuary, then the Estuarine Delta is formed which is submerged under marine water. Examples are Narmada River, Congo River, Amazon River and Hudson River.

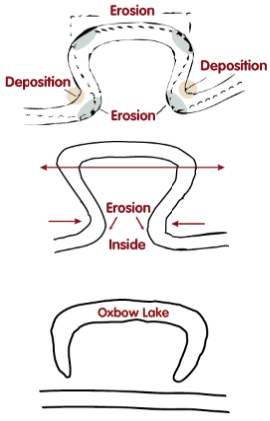
Cuspate Delta

Cuspate delta are pointed. They are shaped by regular, opposing, gentle water movement as seen at the Tiber river.

Oxbow lakes

The Oxbow lakes are formed by the depositional and erosional actions taking place simultaneously. Please note that excessive meandering would result in Oxbow lakes.

How Oxbow lakes are formed?



On the inside of the loop, the river travels more slowly leading to deposition of silt. Meanwhile water on the outside edges tends to flow faster, which erodes the banks making the meander even wider. Over time the loop of the meander widens until the neck vanishes altogether. Then the meander is removed from the river's current and the horseshoe shaped oxbow lake is formed.

Black Swamps

When the water spills out onto the flood plains, the heaviest material drops out first and finest material is carried over a greater distance. This fine grained alluvium would hold much water and would give rise to a wetland which is called Black swamps or simply swamps.

Landforms made by River Transportations

The dissolved solids in the rivers travel downstream and become a part of Ocean. The particles of clay, silt and fine grains are carried in suspension. Whenever a soft rock obstructs the course of stream and is eroded and sediments are scattered all around, it would be called **Eddies.** These **Eddies** sometimes look like discs and so are called **potholes**. The large potholes are called Plungepools.

Drainage patterns

Drainage pattern refers to the river system that is developed by the main river and its various tributaries. The higher landform that separates the two drainage patterns is called the water divide. The following diagram shows major drainage patterns.