Block – 2

BLOCK INTRODUCTION

The term geomorphic relates to the form of the landscape and other natural features of the earth's surface. The forces causing physical and chemical changes on earth's surface are known as **geomorphic processes.** All changes take place under the influence of certain forces working continuously within the earth as well as over the surface of the earth. In this block Earth's movement have been discussed. Fifith unit gives you the basic information regarding the forces that are affecting the landforms of Earth. These forces are operating for ages, and they are still continuing to operate. Slow forces are slow and a few sudden. The endogenic and eugenic forces have been discussed in this unit. The Sixth unit have been studied abot the Diastrophic force, which is slow in nature, has been further classified as Epierogenetic and Orogenetic forces. This unit gives details about the epirogenic and Orogenic movement and its types, types of mountain and stage of mountain building, geosynclines and its types and various theories of mountain building have been discussed in this unit.

Seventh unit gives information about the meaning and structure of volcanoes, its products, materials, causes, types, landforms formed by volcanic activities and its effects, and the world distribution of volcanoes have been discussed. Eighth unit provides you a basic knowledge about the earthquake. You will come to know that the causes of earthquakes, why and where it occurs? How can we measure the intensity of earthquakes? The effects of earthquakes and others.

UNIT – 5

EARTH'S MOVEMENTS –ENDOGENIC & EXOGENIC : FOLDS AND FAULTS

Structure:

5.9: Types of Faults

- 5.9.1 Normal Fault
- 5.9.1.1 Horst and Block Mountains
- 5.9.1.1.a Tilted Block Mountains
- 5.9.1.1.b Lifted Block Mountains
- 5.9.1.2 Rift Valley/Graben
- 5.9.1.3 Reverse/Thrust Faults
- 5.9.1.4 Lateral/Strike Slip/Wrench Fault
- 5.9.1.5 Dip Slip Fault
- 5.9.1.6 Oblique Slip Faults
- 5.9.1.7 Step Fault
- 5.9.1.8 Tilted Fault block
- 5.9.1.9 High Angle Fault
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- 5.9.1.13 Longitudinal Fault
- 5.9.1.14 Transverse Fault
- 5.9.1.14 Radial Fault
- 5.9.1.15 Peripheral Fault
- 5.9.1.16 Transcurrent fault
- 5.9.1.17 Hinge Fault
- 5.9.1.18 Retreat Scrap
- 5.9.10 Significance of Faults
- 5.9.11 Disadvantages of Faults

5.10: Let us sum up

5.11: Key Words

5.12: Questions for self study

5.13: Further Reading

5.0: OBJECTIVES

This unit provides you the basic information regarding the forces that are affecting the landforms of Earth. These forces are operating for ages, and they are still continuing to operate. Slow forces are slow and a few sudden. After studying this unit, we will be able to;

(i) Identify the forces affecting the landforms.

(ii) List out the endogenetic forces operating.

(iii) Understand the exogenetic forces.

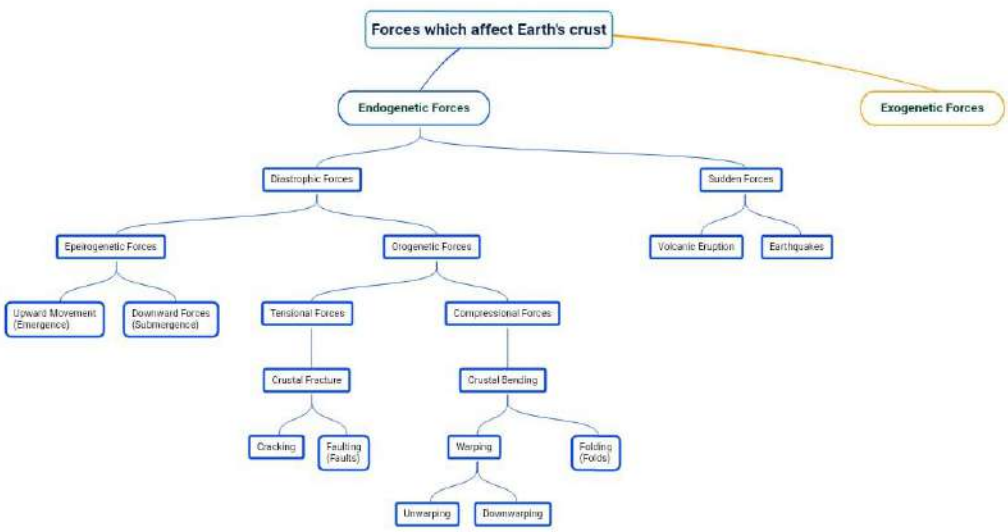
5.1: INTRODUCTION

Several types of landforms are found over the surface of the Earth. A specific geomorphic feature or a natural shape on the earth's surface is known as a landform. Ex: Mountain, valley, plateau, plain, etc. These landforms are not constant. They are affected by various natural processes at different times. In this unit, we are going to discuss the type of forces operating, modifying, and creating various types of landforms.

5.2: TYPES OF FORCES

There are certain forces playing dominant roles in shaping the surface of the earth, which may be both constructive and destructive. All the geological processes can be conveniently grouped into two types based on their origin. They are Endogenous and Exogenous movements or processes.

Figure: 5.0



5.2.1. Exogenic Forces:

Exogenic forces are operating over the surfaces of the earth. They derive energy from external forces like the Sun, atmospheric pressure, winds, rainfall and snowfall, forces of gravity, and the activity of organisms. As these processes are limited to the surface of the earth, they are also so-called **'Epigene'** processes. External forces are interrelated and collectively affect the landforms above sea level. Here the term landform refers to the shape or form into which a piece of land is altered by natural agents. These forces break the rocks and carve out diverse landforms. The materials are carried away and deposited elsewhere to create new landforms. Since these forces remove the unevenness on the surface of the earth, they are even called destructive forces.

5.2.2 Endogenetic Forces:

Endogenetic or 'Hypogene' processes are those processes that originate inside the earth. These processes derive energy mainly from the thermal energy of the mantle and crust. This thermal energy is further sourced by the heat produced by the radioactive decay of various elements present inside the crust. Endogenic forces are responsible for a number of phenomena like earthquakes, volcanic activities, emergence and development of continents, ocean troughs, and many more and are hence called constructive forces. The landforms produced by the endogenetic forces are further modified by exogenetic forces. Endogenic forces or movements are further classified into two types. They are;

1.Diastrophic Forces 2. Sudden forces

5.2.2.1. Diastrophic Forces:

Diastrophic forces are very slow forces, but they cause a lot of deformation of the earth's crust. These activities are related to the internal movements of the earth. The slow changes caused by the forces operating within the earth are called tectonic movements. The crustal movements which cause the rocks to shift either horizontally or vertically or in any other direction are known as Diastrophism. The term Diastrophism is derived from a Greek word 'Diastropor' meaning turned or twisted. According to P.G.Worcester (1965), the term diastrophism includes all crustal movements of the earth. These forces are operating for many thousands of years. Diastrophic forces are also called 'Constructive Forces' because they affect a larger part of the earth and produce many relief features like mountains, plateaus, plains, etc. The diastrophic forces are further classified into two types. They are;

(i) Epeirogenic/Epeirogenetic Forces (ii) Orogenic/Orogenetic Forces

5.2.2.1.i Epeirogenetic Movement:

The term Epeirogenic is derived from two Greek words, ‘Epios’ meaning continent and ‘Genesis’ meaning origin. This movement is predominantly vertical. It causes depressions or elevation of large areas of the earth’s crust without much deformation. Here the elevation or upliftment is replaced by subsidence in other areas. Near the coastal areas, we can find both upliftment and subsidence. Example: Coastal regions of Great Britain, Gulf of Bothnia, and Coastal regions of Holland. Hence this movement is also known as the continent building or oscillatory movement.

The Epeirogenetic movements are slow and continuous. Here sea level is used to measure the upliftment (elevation) or subsidence. Changes in a sea-level position related to land are known as ‘Eustatic’ changes. According to the direction of this movement (Epeirogenetic), it is classified into two types. They are;

(a) Upward Movement: It causes the upliftment of continental masses. When a part of the continental block rises above the nearly surface is known as uplift. Example: Atlantic Coastal Plain of South-East of USA, Raised coral reefs of Peru and Cuba, Coastal lines of Gujarat, etc...

The upliftment of coastal lands above sea level is known as Emergence.

(b) Downward Movement: When the landmasses move downwards comparing to the surrounding area is known as subsidence. Ex: Some parts of Holland.

When the land near the coast is moving downward or subsides below sea level is known as Submergence. Ex: Some parts of Gangetic delta, Fjords of Norway, etc...

5.2.2.1.ii Orogenetic Movements:

The term ‘orogeny’ is derived from the Greek word ‘oros’ meaning mountains and ‘Genesis’ meaning origin. It explains the mountain-building processes. G.K.Gilbert, an American geologist, first introduced the term orogeny in 1890. These movements are caused by horizontal forces in the earth’s crust in a tangential direction. Due to this, the rock layers are compressed and folded. Orogenic movements are periodic in nature and effects severely. The horizontal force/Orogenic force works in two ways.

When these forces act in the opposite direction (⇨ ⇦ is known as Divergent or Tensional force. It causes cracks, fractures, faults, and ruptures in the crust. When this force acts in the same direction, it is known as convergent or compression force. This force is responsible for folds or crustal wrapping.

5.3: FOLDS

Now, we will discuss in detail the compressional force and the landforms as the result of it. This force will form a wave-like bend in the rock strata, which is known as 'Folds.' Sedimentary rocks have greater flexibility than any other rocks. Some parts of the rock layer bend upwards, and others downward. The upfolded rock layer, which looks like an arc, is called as 'Anticline.' The down folded structure which folds like a trough, is known as 'Syncline'. The shape and size of the folds depend upon the nature of rocks, direction, and amount of compression force.

5.3.1 Parts of the Fold:

The fold consists of two main elements. The two sides of a fold are known as 'Limbs' and 'Flanks/Shranks'. The hinge is a zone where the folded bed or the layer having maximum curvature. The wavelength of the fold is the distance measuring the highest points of two successive folds.

A hinge is a line running through the points of maximum curvature. The Hinge maybe horizontal or inclined, or vertical. The axial plane is the surface connecting all the hinges. In other words, it is an imaginary plane that divides the fold symmetrically as possible. The hinge is at equidistance from both the limbs at any point of the axial plane, and each fold has an axis of anti-cline.

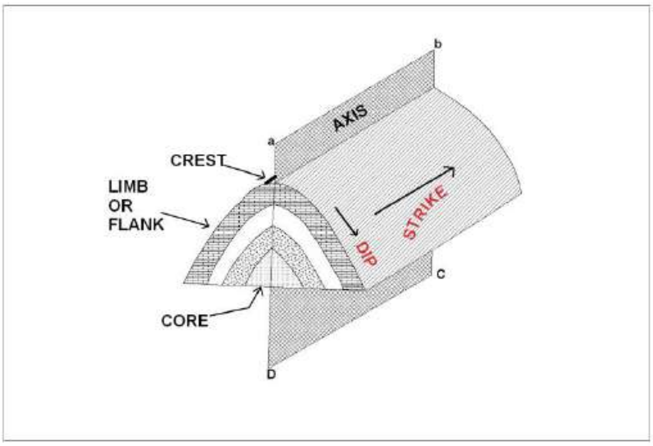
Axis is the line of intersection of the axial plane and the ground surface. **Core** is the inner part of the fold.

A trough is a line occupying the lowest part of the fold. It is a line connecting the lowest parts of the same bed. The plane connecting these lines is called as 'Trough Plane'. The trough is a concave portion of the undulating landform.

The crest is the convex part of the fold. The plane or surface formed by all the crests is called 'Crystal Plane.

Figure: 5.1

Parts of a Fold



AC & AB = Limbs of the Fold, B & C = Troughs

The inclination of the rock bed with respect to the horizontal plane is called ***'Dip'.*** It is measured with the help of the instrument ***'Clinometer.'***

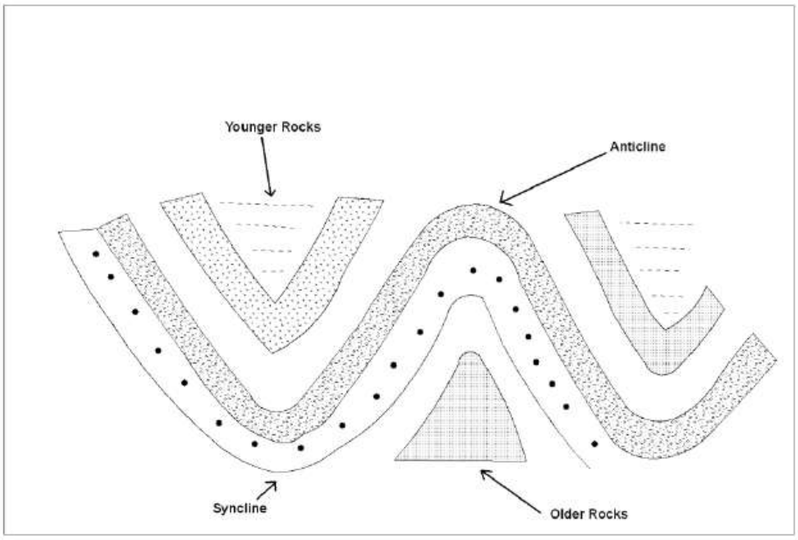
A strike is the direction of a line formed by the intersection of the bedding and horizontal plane. The direction of the dip is always at a right angle to the strike.

Altitude is a three-dimensional orientation of some geological features like a bed, a joint, fold, or a needle. The Angle of Inclination of the fold axis with horizontal as measured in the vertical plane is known as Pitch or Plunge of the Fold.

5.3.2 Anticlines:

The word Anticline is derived from Greek words 'Anti' meaning opposite and 'cline' meaning inclined. It is the uploaded or up-arched, or convex rock strata. Younger rocks are found upward, while older rocks are present in the centre. When the two sides of the fold(limb) are uniform, it is known as 'Symmetrical Anticlines'. When the slopes are unequal, it is called 'Asymmetrical Anticlines'.

Figure: 5.3
Anticline and Syncline



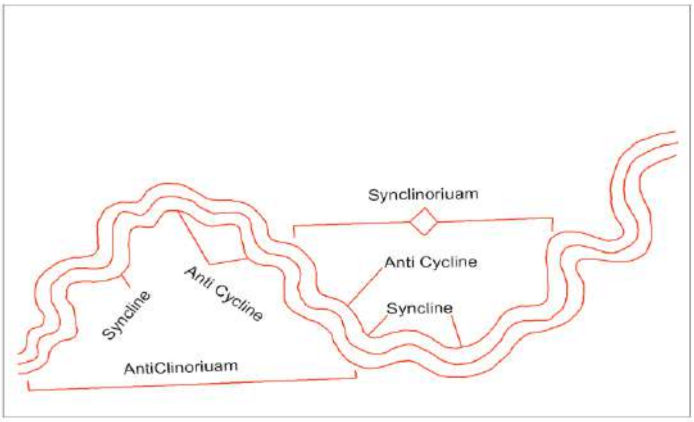
5.3.3 Syncline:

The term syncline is derived from the Greek word meaning 'inclined together' / When the sides of the fold (Limb) dip towards each other, is called Syncline. It is a fold that is convex downwards or concave upward. Normally, younger rocks are found in the centre of the fold.

Anticlinorium: In one big anticline, we will find a series of folds. It is known as Anticlinorium. It is formed due to unequal forces and leads to unequal folds.

Synclinorium: Synclinorium is an extensive syncline having a number of undulations. Irregular folding of rocks and irregular compressive forces are responsible for this relief feature.

Figure: 5.4
Anticlinorium and Synclinorium



5.4: GEOSYNCLINES

Geosynclines literally means 'earth syncline'. It is a large depression with hundred miles long, and tens of miles wide in tons and tons of sediments can be deposited. Ex: Appalachian Geosynclines during the Palaeozoic era, etc…

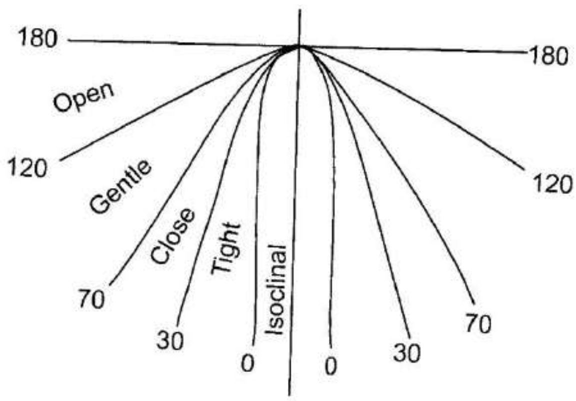
5.4.1. Geanticline: It is a broad uplift. It may extend from a few miles to hundreds of miles in length and width. Its size is similar to that of Geosyncline. Ex: The great plains of Western North America, Gulf of Mexico, Mississippi basin, etc… A Geanticline may be found either outside or inside a Geosyncline.

5.5: TYPES OF FOLD

There are several factors that affect the formation of folds. Some folds are simple, and some are complex. The forces operating for each case may be different in direction and duration. Based on the degree of compression, the position of the axial plane, mode of occurrence, behavior with depth, folds are classified into several types. The most important is, the angle between two limbs of a fold is known as the Inter-limb angle. It is an indicator of openness or tightness of a fold. Based on increasing of tightness, the folds are classified into five types. They are;

1. Gentle Fold – 180^0 to 120^0
2. Open Fold – 120^0 to 70^0
3. Close Fold – 70^0 to 30^0
4. Tight Fold – 30^0 to $>0^0$
5. Isoclinal Fold - 0^0

Figure: 5.5
Types of fold based on the interlimb angle of the fold



Based on the nature and direction of the stress of the axial plane, a fold may be in any position. Based on the position of the Axis plane, it is classified as;

1. **Symmetric Fold:** It is also known as upright folds. The two sides of a fold are inclined equally in opposite directions. It is an example of an open fold and is very rare in the world.

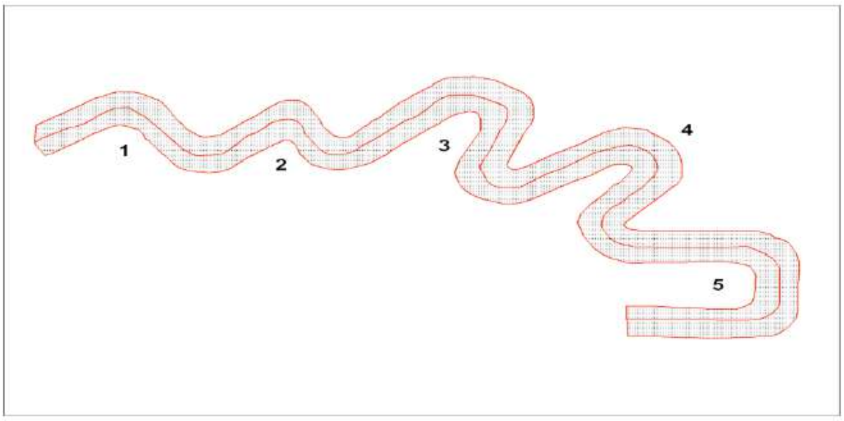
2. **Asymmetrical Fold:** Here, the limbs are unequal and inclined at different angles.

3. **Monoclinal Fold:** It is formed due to vertical force and unequal compression. Here one limb inclines moderately, and another side of a fold inclines steeply.

4. **Isoclinal Fold:** The term Isoclinal is derived from Greek words meaning 'equally inclined'. Here the two sides of a fold dip at equal angles in the same direction. Many recumbent folds are also isoclinal.

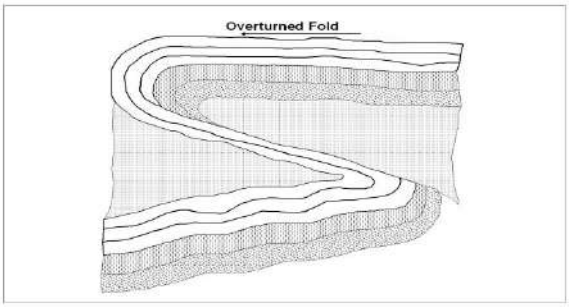
5. **Recumbent Fold:** These are extreme overturned folds. When compression is so strong that both limbs of the fold become parallel and horizontal, one limb might lie vertically above the other. The lower limb is inverted or reversed.

Figure: 5.6



6. **Over turned Fold:** Here, one limb of the fold is pushed on another fold due to great compressive force. Limbs are rarely horizontal.

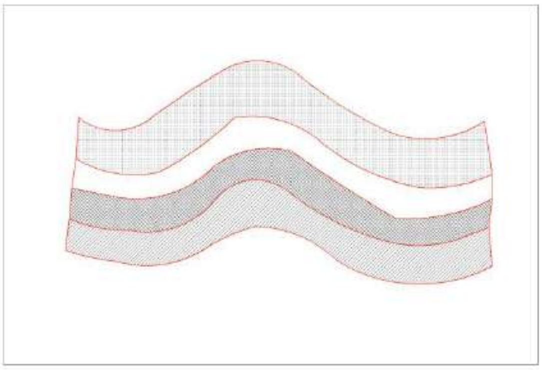
Figure: 5.7



7. **Fan Fold:** Sometimes, the limbs of a fold may be over-compressed on both sides. Extreme pressure on an anticline or syncline leads to limbs will become closer to each other. Due to this, the limbs of the anticline dip toward each other, and the limbs of the syncline dip away from each other. This kind of fold is known as 'Fan Fold.'

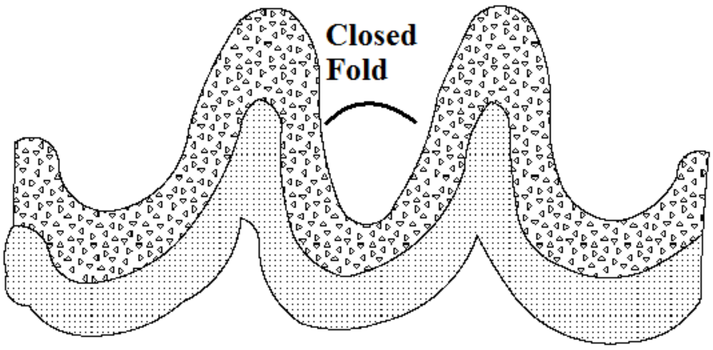
8. **Open Fold:** Here, the angles between two liquids of a fold are more than 90^0 but less than 180^0 as shown in figure 5.8.

Figure: 5.8
Open Fold



9. **Closed Fold/Tight Fold:** These folds are formed due to compressive force. In this type, the angle between the two limbs of a fold is acute.

Figure: 5.9
Closed Fold



10. **Parallel Fold:** Here, the thickness of the layer of a fold is the same, and it is perpendicular to the fold surface. Folded layers are parallel to each other.

11. **Similar Fold:** In this type of fold, the thickness of the layer measured in parallel to the axial surface. They have similar geometry in both upward and downward directions.

12. **Chevron Fold:** The hinges of these folds are sharp and angular.

13. Box Fold: Here, the crust is broad and flat. On either side of the flat crust, two hinges are present.

14. Reclined Fold: When the axis plunge directly down the dip of the axial surface is known as Reclined Fold.

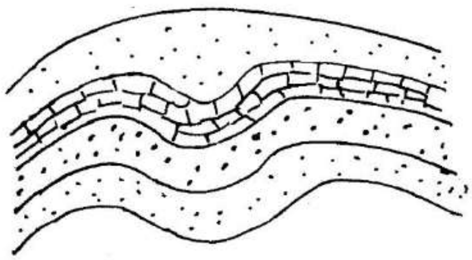
15. Concentric Folds: This is a special type of parallel fold in which the adjacent fold surfaces have a common centre of curvature for the arcs of circles.

16. Kink Bands: They are narrow bands that are only a few feet wide. Here the beds are so steep or gentle compared to other adjacent beds.

17. Drag Folds: These are minor folds developed within the body of weaker beds and surrounded by stronger beds. These are formed when a stronger rock bed slides on weaker rock beds.

18. Supratenous Folds: These are formed when folding takes place with sedimentation. Here anticlinal ridges are thinner due to erosion, and troughs of synclines are thicker due to sedimentation processes.

Figure: 5.10
Supratenous Fold



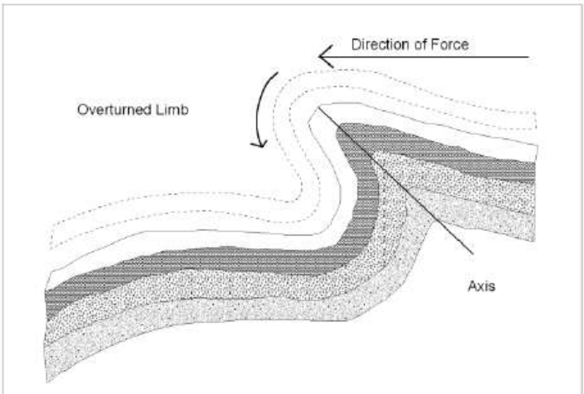
19. Domes and Basins: Domes are anticlinal arch in which beds dip away in all directions from a common centre. The reverse conditions of basins is domes, where beds are dipping in from all directions.

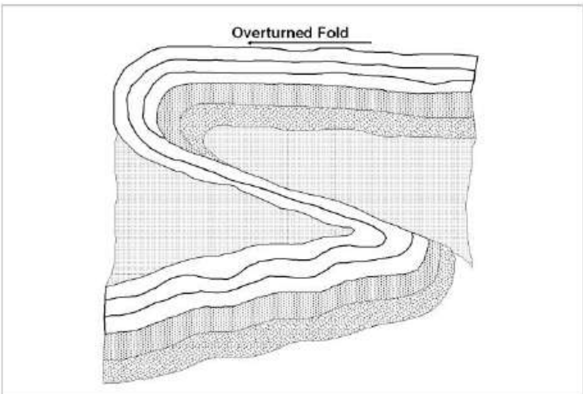
20. Homocline: It shows a sequence of strata dipping in the same direction at a uniform angle.

5.6: NAPPES

These are formed due to complex folding caused by horizontal movement and compressive force. When compressive force increases over a limb of the recumbent fold, which slides over the other fold, this process is called ‘Thrust’. The plane along which one part of the fold is thrust is known as the ‘Thrust plane’. The upper part of the thrust of a fold is known as the ‘over thrust fold’. When the compressive force is further increased, it breaks up the axis of the fold, and the rock beds in the bottom move upward. When compression force continues further, the broken limb of the fold is thrown away from its original place to a faraway place. The rock structure of this broken limb is different from the rock structure where it is found. This broken limb of the fold is known as ‘Nappe’. Alps mountains in Switzerland consist of several nappes. These are also found in the Himalayas.

Figure: 5.11
Formation of Nappe a. Stage of Ourturned fold b. Overriding one limb of the fold on another





Different kinds of folds are formed due to variation in vertical and compressive force, their intensity, duration, nature of rocks. It indirectly helps us to determine the landforms that are produced by various agents of denudation. The deformations of the earth, whether large or small, are of great significance in determining the topography in present-day in any place.

5.7: CRYSTAL FRACTURES

In the earlier topic, we have discussed the diastrophic forces which are operating under the surface of the earth. You know that Orogenic force can be classified as Tensional and compressional force. We have studied the compression force, its effect, and resultant land forms. Now we will discuss how tensional force is also responsible for the formation of new land forms. When a force acts in the opposite direction (←→), it causes tension in the rock beds and results in fractures, ruptures, and faults.

5.8: FAULTS

According to Worcester (1965), a fault is a fracture or fissure in the earth along which one slide has moved with reference to the other side. Faults are the most common geological feature found in rocks. These are discontinuity showing visible displacement of some pre-existing features. Faults are ruptures along which the opposite walls have moved past each other (Maryland.P.Billings-2005). Faults vary from few inches to hundreds of feet. Faults cause problems for engineers in the construction of heavy structures. But they are useful because groundwater and minerals are accumulated in fault planes.

The strength of rock and the amount of force decides the type of fault. This occurs in weaker zones. In these places, the Earth's movements were regular for a long time. These faults are called 'Active Faults'. Ex: San Andrea's fault in 1906 caused an earthquake in California, etc.

5.8.1 Parts of a Fault: Various names have been given to explain the various parts of the faults. They are helpful in the identification and classification of faults. The most important are;

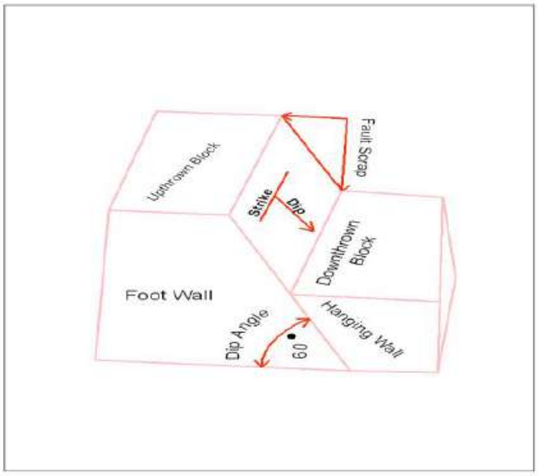
5.8.1.a Fault Plane: It is the place where fracture (crack) occurs in the rock, and this place blocks will move apart from each other. Intersection with the surface is known as fault trace or fault outcrop. Sometimes fault plane may not be smooth and comprises a number of fractures. It is known as the Fault zone or Shear zone.

5.8.1.b Fault Line: The trace of a fault on the earth's surface.

5.8.1.c Strike: It is the trend of a horizontal line in the plane of the fault.

5.8.1.d Dip: It is the angle between a horizontal surface and the plane of the fault. The dip of the fault is measured as both direction and amount of inclination.

Figure: 5.12
Parts of a Fault



5.8.1.e Hade: Hade of the fault is the measure of the angle between the vertical plane and the fault plane. It is complementary to the dip (i.e., Hade = 90^0- dip).

5.8.1.f Hanging and footwall: Fault is the result of breaking the rock strata into two blocks. They are hanging walls and footwalls. The block above the fault is called a hanging wall, and the footwall is that wall lying below the fault plane.

5.8.1.g Fault trace/ Fault outcrop: The intersection of the fault with the surface of the earth.

5.8.1.h Fault scrap: An upstanding structure with a steep side that is formed due to relative displacement on either side of the fault line.

5.8.1.i Slip of Fault: It is used to indicate the relative displacement of formerly adjacent points on opposite sides of the fault. Net slip is the total displacement.

5.8.1.j Throw and Heave: Throw is the vertical component of the apparent displacement of any two points formerly in contact. Heave is the horizontal component of the apparent displacement determined in a vertical section at right angles to the fault strike.

5.8.1.k Rake of the Fault: Rate is the angle that a line in a plane makes with the horizontal line in that plane.

5.8.1.l Slickenside: These are polished surfaces produced by the grinding action during the movement of faulted blocks.

5.8.1.m Gouge or Fault Breccia: Angular fragments and fine powder produced when the faulted block moves.

5.8.1.n Fault Zone: It is a place where a number of faults are found.

5.8.1.o Net Slip: The total displacement due to a fault.

5.8.1.p Trace slip: It is the component of net slip parallel to the trace of the bed on the fault.

5.8.1.q Shift: This term is used to refer to the displacement on opposite sides of the fault and outside the dislocated zone.

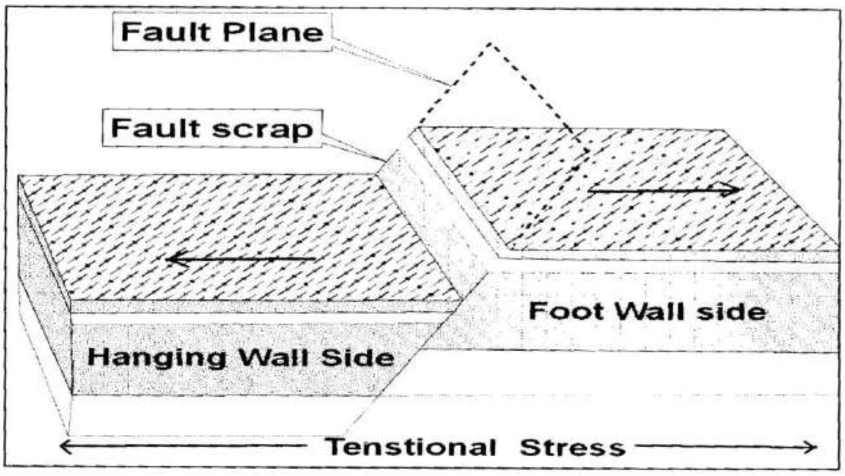
5.9: TYPES OF FAULTS

Several types of faults are found in different types of rocks. The nature of rocks, direction and duration of forces are the most important factors determining the type of faults. The classification is based on the movement of blocks, the relation of the fault attitude to the adjacent beds, the direction of net slip, the amount of dip of the fault, and the mode of occurrence of the faults. The most important types of faults are;

5.9.1 Normal Fault: These are formed due to tension and lengthening or extension of the faulted beds. It is associated with crustal splitting. Here the hanging wall moves downwards due to maximum stress in the vertical direction. This kind of fault is known as Normal Fault.

In a normal fault, the hanging wall moves downward relative to the footwall, and this is called Gravity/Tensional Faults. Normal fault creates two major topographic features. They are;

Figure: 5.13
Normal Fault



5.9.1.1 Horst and Block Mountains: An up-thrown block that stands above the surrounding place is known as Horst. It is surrounded at least on two sides by Fault Planes. It looks like a plateau or mountains with a flat top, steep and straight slides. Example: Shillong Plateau.

Block Mountains are also known as Fault Block Mountains or Horst mountains. These are formed by compressional and tension forces. It is a land block between two faults or either side of a rift valley or a Graben. If there is a fault in the ground surface, block mountains are formed. There are two types of Block Mountains;

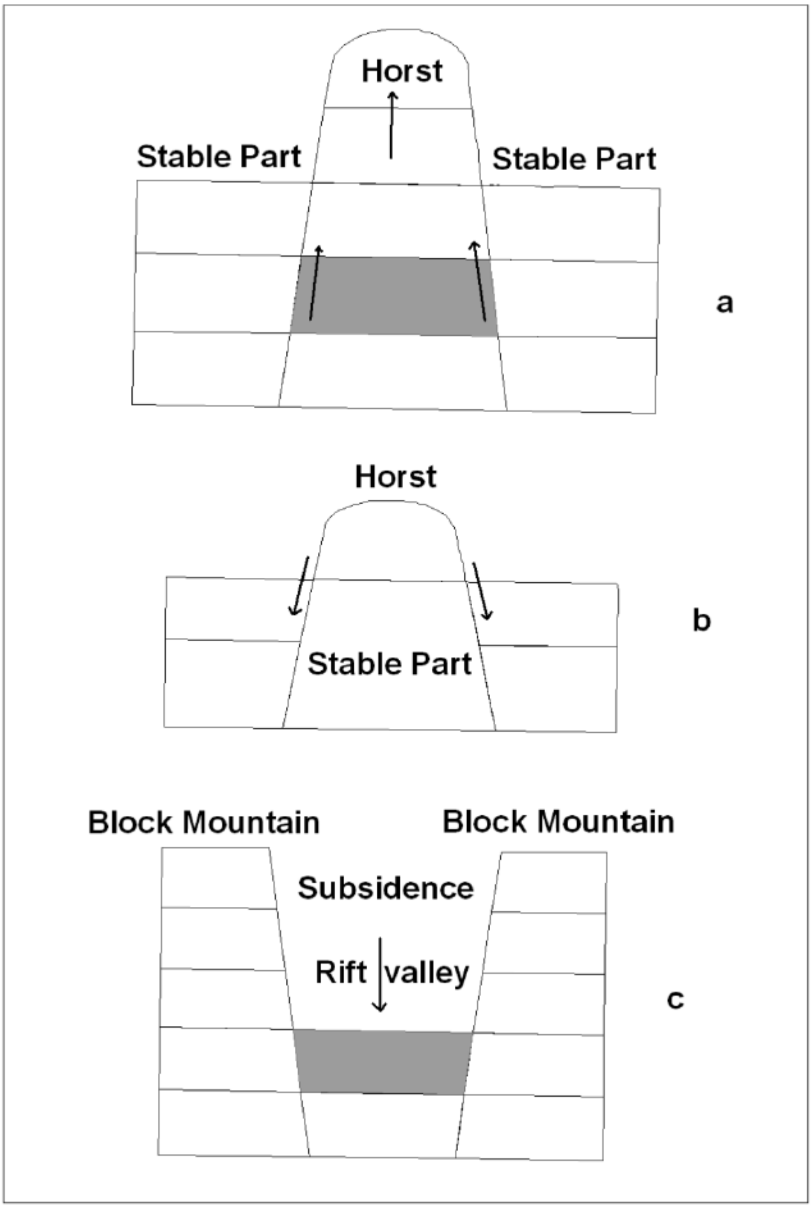
5.9.1.1.a Tilted Block Mountains: These are having a steep slope at one end and a gentle slope on the other end.

5.9.1.1.b Lifted Block Mountains: They consist of a flat top, and both sides are steep. The Sierra Nevada Mountains of California are probably the largest fault block in the world. It is 400 miles long, 50 miles in width, and on average, its height varies from 8000 to 12000 feet above sea level. There are several examples of Block Mountains in the world. Example: the Vosges and Black forest mountains bordering rift valley in Europe, Utah province in the USA, etc.…

5.9.1.2 Rift Valley/Graben: A long fault depression between two normal faults is called a Rift valley or Graben. It is a tectonic valley or trench-like structure having steep and parallel fault scraps. These are commonly found with Horsts. Example: Valley of Jordan River in Israel, Rhine river valley between the Black Forest and the Vosges in Germany. Here rivers have carved the valleys, but valleys are older than the rivers. Example: Great Rift Valley in Africa.

In certain cases, the central block in reverse fault is forced to go down. This is caused by the fracturing of rock strata due to horizontal pressure. Those valleys formed by this type of compression are called Ramp Valley. Example: Brahmaputra river valley.

Figure: 5.14

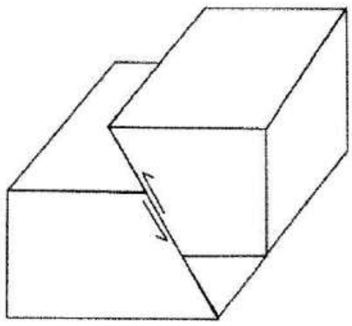


a. Block mountain formed due to rise of the middle block
b. Due to downward movement of side blocks, block mountain is formed
c. Formation of block mountain due to downward movement of the middle block.

5.9.1.3 Reverse / Thrust Faults: When the hanging wall in the fault moves upwards relative to the footwall, it is known as Reverse Fault. Here the vertical pressure is less and horizontal stress is maximum. Due to excessive compression, one rock block overrides the other fault plane. Here the fault dip is more than 45^0.

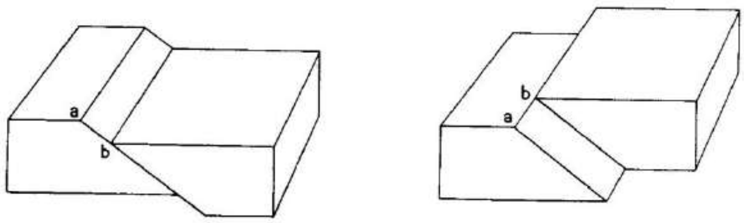
The term thrust is generally used to express low angle reverse faults in which the hanging wall has actually moved up with respect to the footwall. Here the dip is less than 10^0 and has a large net slip. These faults are found in the Himalayan and Alps mountains. It is also described as overthrust and under thrusts.

Figure: 5.15
Reverse Fault



5.9.1.4 Lateral/Strike-Slip/Wrench Fault: When in horizontal movement, the rock blocks are displaced along the fault plane. In a fault, the net slip is in the direction of the strike of the fault is known as strike-slip fault.

Figure: 5.16

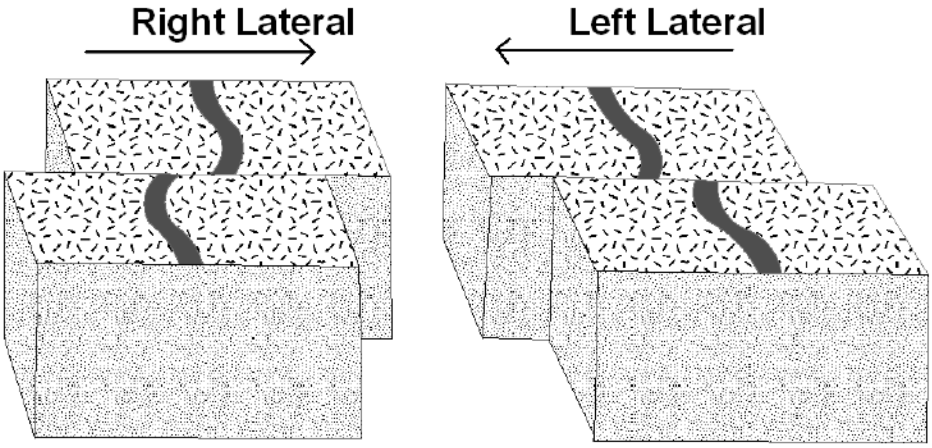


ab is the Net slip

A ***Wrench fault*** is a strike-slip fault in which movement of the blocks is parallel to the strike of the fault and dip of the fault plane is very steep or vertical.

When displacement is parallel to the strike of the fault, the opposite wall of the fault moves towards the right; it is called as right slip fault. When the opposite wall moves towards the left, it is called the Left slip fault as shown in figure 5.17.

Figure: 5.17
Strike-slip fault



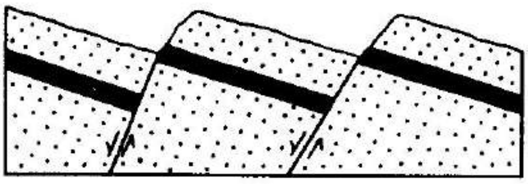
5.9.1.5 Dip Slip Fault: It is formed when slip occurs parallel to dip of the fault are named as dip-slip faults.

5.9.1.6 Oblique Slip Faults: These are the faults with a net slip parallel neither to dip nor to strike of the fault but rather inclined to both of these.

5.9.1.7 Step Fault: When there is a continuous downward displacement of all the down-thrown blocks, a series of faults occur in an area. It is known as step fault.

5.9.1.8 Tilted Fault block: Normal faulting is accompanied in many instances by tilting of the blocks on or both sides of the fault resulting in tilted fault blocks.

Figure: 5.18
Tilted fault block



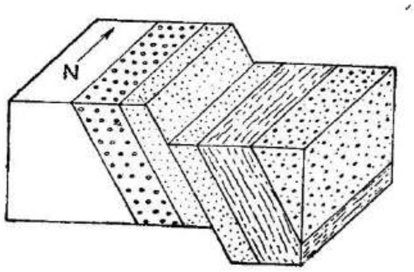
5.9.1.9 High Angle Fault: When fault planes dipping at angles of more than 45^0.

5.9.1.10 Low Angle Fault: Here the angle of the fault plane is less than 45^0.

5.9.1.11 Enechelon Fault: Small-sized faults that overlap each other are known as Enechelon fault.

5.9.1.12 Bedding Fault: It is a type of strike fault. Here the strike is parallel to the bed.

Figure: 5.19
Bedding Fault

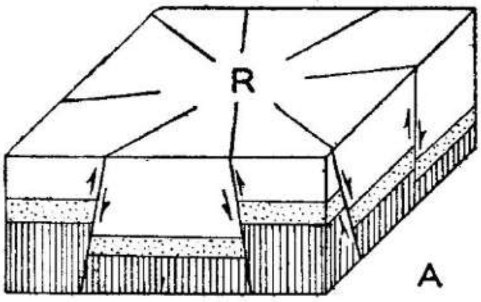


5.9.1.13 Longitudinal Fault: Strikes are parallel to the strike of the regional structure.

5.9.1.14 Transverse Fault: Here strike is perpendicular or diagonal to the strike of the regional structure.

5.9.1.14 Radial Fault: The fault which radiates from a common point or direction.

Figure: 5.20
Radial Fault

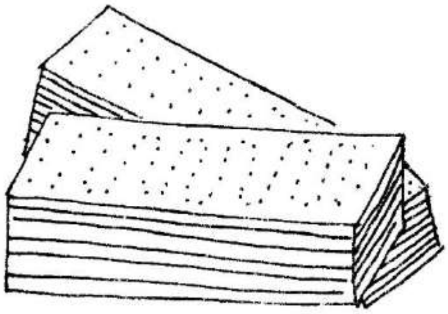


5.9.1.15 Peripheral Fault: In a region, if the majority of faults show curved or arcuate fault.

5.9.1.16 Transcurrent fault: In this type of fault, the blocks move against each other. These are also called Tear faults.

5.9.1.17 Hinge Fault: Here, the blocks move along a hinge point. The block rotates about a point, and the amount of displacement increases as we move farther from the hinge point. This fault is also known as a pivotal or rotational fault.

Figure: 5.21
Hinge Fault



5.9.1.18 Retreat Scrap: Due to erosion, fault and fault line scraps may retreat. New cliffs parallel with original scraps are formed. But they are located far away from the trace of the fault, at the foot of the cliffs.

5.9.10 Significance of Faults: Several mineral and power resources are found along the fault regions. In porous beds, petroleum is found. The groundwater level is more in fault planes. Waterfalls can also be a result of faulting.

5.9.11 Disadvantages of Faults:

5.9.11.a Fault rocks will form very weak foundations in several regions. These places are not suitable for the construction of dams and reservoirs.

5.9.11.b Underground water will come out at shear and fault zones. This results in the wastage of groundwater.

5.9.11.c When a shear zone is filled with water, it is difficult to withstand huge structures over the surface.

5.9.11.d If faulting product like Breccia is found under the buildings and other structures, they create a lot of problems.

5.10: LET US SUM UP

In this unit, you have studied the compression and tensional forces. These forces are responsible for the occurrence of folds, faults, and joints. These forces are forming various topographical features over the surface of the earth.

5.11: KEY WORDS

Folds: Wave-like bend in the rock strata.

Limbs: Two sides of a fold are known as Limb or Flanks.

Anticline: The upfolded rock strata (Arch like form)

Syncline: Down folded structure or trough-like feature.

Geosyncline: Large depression.

Fault: Fracture or fissure in the earth, which one side has moved with reference to the other.

Joint: It is a fracture in the crustal rocks where no substantial movement of rock takes place.

5.12: QUESTIONS FOR SELF STUDY

1. Explain the Endogenic and Exogenic forces in detail.
2. Discuss the various type of folds with neat diagrams.
3. Describe the types of Faults.

4. Write short notes on – Anticlinorium, Synclinorium, Normal Fault, Rift valley, and Block Mountain.

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UNIT – 6

CONCEPT OF GEOSYNCLINES AND MOUNTAIN BUILDING

Structure:

6.0: OBJECTIVES

In this unit, it provides the knowledge of –

- Epeirogenic movement and its type
- Orogenic movement and its type
- Types of mountains
- Stages of Mountain building
- Types of Geosynclines
- Theories of Mountain building

6.1: INTRODUCTION

We have already discussed the forces operating or modifying the earth's surface. These are called Endogenetic and Exogenetic forces. The endogenetic forces which are operating under the surface have been further classified as sudden and diastrophic forces. The Diastrophic force, which is slow in nature, has been further classified as Epierogenetic and Orogenetic forces. This unit will give you details about these forces.

6.2: DIASTROPHIC FORCE

The term 'Diastropos' is a Greek term, which means 'turned or twisted or distorted.' Any kind of crustal movement, gentle or severe, continuous or periodic, which causes the rocks to shift vertically or horizontally or in any other direction is known as 'Diastrophism.' The diastrophic forces operate very slowly, and their effects are found for a long time. Larger parts of the earth are affected by these forces and cause meso relief features like mountains, plateaux, plains, lakes, faults, and others. These forces are broadly classified into two types. They are –

1. Epierogenic movement.
2. Orogenetic movement.

6.3: EPIEROGENIC MOVEMENT

The word 'Epierogenic' is derived from two Greek words 'Epiros' means continent, and 'Genesis' means origin. It causes upliftment and subsidence of continental masses through vertical movements. It affects larger parts of the earth's crust without much deformation (It is a process by which rocks change shape, tilt, or break in response to squeezing, stretching, or shearing). Deformation produces geological structures like cracks (joints), folds, faults, and foliation.

This type of movement is also known as 'Continental building' and 'Oscillatory movements. According to the direction of epierogenic movement has been classified as upward and downward movement. This movement occurs due to variation in ***Isostatic balance.*** This process is very slow but continuous in nature.

6.4: OROGENIC MOVEMENT

The term 'Orogen' is derived from two Greek words, 'Oros' meaning 'mountain' and 'Genesis' means 'formation'. The term Orogeny was first introduced by the American Geologist 'G.K.Gilbert in 1890 to explain the mountain building process. This movement is caused due to horizontal forces operating in the earth's crust which are tangential to the surface. These movements are periodic in nature and severe in their effects. It causes compression and tension in the crust, creating Stress and Strain.

The orogenic force works in two ways. One works in the opposite direction, which is known as Divergent or Tensional force (← →). It causes rupture, cracks, faults, and fractures. Another force acts toward each other, which is known as convergent or compression force (→ ←). It causes crustal bending, which results in folding or wrapping.

6.5: MOUNTAIN BUILDING

Meaning: Mountain is a relief feature of the second order. It is an uplifted part of the earth that is higher than the surrounding place. Prof.Flinch has described a mountain as a 'land block its height is at least 900 meters above the sea level, with a slope of $25^0$to $35^0$to the horizontal plane'. If the height of this uplifted block is less than 900 meters, it is known as a hill or mound'.

There are several types of mountains. They are –

1. **Mountain Ridge:** It is a long, narrow, and high hills. Generally, one side of the ridge is steep, while the other side is moderate. Some ridges have symmetrical slopes.
2. **Mountain Range:** It consists of mountains and hills having several peaks, ridges, valleys, and summits.

3. **Mountain Chain:** It has several parallel long and narrow mountains of different periods.
4. **Mountain System:** Mountain ranges are separated by several valleys. The mountain ranges are of the same period.
5. **Mountain Group:** It consists of different mountain systems. Ex: Applachian,
6. **Cordillera:** It is derived from a Spanish term, which means several mountain groups or systems. Ex: Western Cordillera of USA.

6.6: TYPES OF MOUNTAIN

Based on the height of a mountain, its location, orgoenesis and mode of origin, mountains are classified into different types.

6.6.1 I Based on the Height of the mountains:

1. Low Mountains: They are having a height of 700 to 1000 meters.
2. Rough Mountains: These are having a height of 1000 to 1500 meters height.
3. Rugged Mountain: These are 1500 to 2000 meters in height.
4. High Mountain: These are having more than 2000 meters in height.

6.6.2 II Based on Location: Mountains are classified into two types based on location. They are-

1. Continental Mountains: These are further classified into two types. They are –

a. Coastal Mountains- Ex: the Rockies, Andes, the Western Ghats etc., Inland mountains are located in the interior of the continents. Ex: Ural Mountains of Russia, Himalayas etc.,

b. Oceanic Mountains: These are found under the seawater.

6.6.3 III. Based on Orogenesis: The mountains which were formed in different geological periods are coming under this type. It is further classified into four types. They are-

1. **Precambrian Mountains:** This kind of mountains were formed nearly 4000 million years ago. These are almost reduced to plain. Ex: Canadian Shield and Eastern Scandinavia.
2. **Caledonian Mountain:** These were formed 435 million years back. These mountains are located in Norway, North-West of Newsouthwales in Australia, Ireland, Britain etc., These mountains have been eroded into a plateau.
3. **Hercynian or Variscon Mountains:** The mountain building activity which occurred in Precarboniferous period in Hercynian mountains. It began from the end of the Caledonian movement and ended at the beginning of the Alpine

movement. Meseta in Morocco, Altai mountains are examples of this mountain.

4. **Alpine mountain:** This type of mountain was started to form by the end of the Mesozoic era and continued in the tertiary period. The highest mountains were formed during this period. Ex: the Himalayas in Asia, the Alps in Europe, the Rockies in North America, the Andes in South America etc.,

6.6.4 IV. Based on the mode of Origin: Here mountains are classified into four types. They are

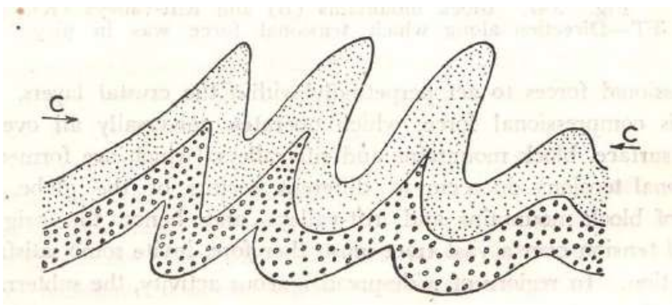
1. **Volcanic Mountains:** Volcanoes generally construct dome-shaped or conical structures around their crater due to the accumulation of lava or pyroclastic materials released by them. The deposition of these materials leads to the formation of mountains. These were formed by volcanic activity. Hence it is known as a volcanic mountain or mountains of accumulation. Ex: Mountain Etna, Vesuvius, Fujiyama, Krakatoa, etc., Volcanic islands are mostly the tops of volcanic mountains formed on ocean floors. Ex: the Hawaiian Islands in the Pacific Ocean, Popa islands, Barren Island, Narcoma in the Bay of Bengal, etc., are examples of volcanic mountains from the deep-sea plains.
2. **Fault or Block Mountains:** Tensional forces are responsible for the occurrence of faults. If a part of the earth's crust observed tension, a series of normal faults would occur. They are found at right angles to the direction of maximum tension. Under these conditions, a number of horsts and grabens are developed. Sometimes on either side of horst, step faults are also formed. Some of the horsts are larger, and these are known as Fault or Block Mountains. On either side of a block mountain, the depressions are known as a Rift valleys. Very large horsts, Grabens, or rift valleys are found in Africa, Sweden, Germany, and the USA. Ex: Ruby and East Humboldt mountains of Nevada are examples of Block Mountains. The great rift valley of Africa runs from East Africa to Syria. The Rhine river in Europe flows through a rift valley.
3. **Residual or Relic or Dissected Mountains:** These are formed by erosional work by different agents of denudation. These are also known as mountains of circumvention. They have been worn down from previously existing elevated regions. Ex: Aravallis and Rajmahal hills of India, Mountain Manodnock of USA, etc., The residual mountains stand alone in the surrounding area

reduced in height. After a long time, the process of differential erosion reduces the affected plateau down to a peneplain on which blocks of rocks stand in the form of residual mountains or plateau of remnants. The mountains of the Deccan and Chotanagpur plateau of India are examples of residual mountains.

4. **Fold Mountains:** Whenever compressional forces act within the earth's crust, it squeezes the rock beds and folds them. If the compressional force is so strong, then large folds may form in successive forms. It leads to the formation of 'fold mountains.'

Figure:6.0

Fold Mountains



(C – Compressional Force)

The major fold mountains are-alps in Europe, Rockies of North America, Andes of South America, and Himalayas of Asia are examples of Fold Mountains. Generally, these are located along the margins of continents. Folding and Faulting are most complex in the central areas of these mountains.

Fold Mountains are further classified into different types. They are

6.7. 1 On the basis of nature of folds:

1. **Simply folded mountains with open folds:** These are found in a wave-like pattern. In these, there is a well-developed anticline and syncline.
2. **Complex Fold Mountains:** Huge compressive forces form these kinds of fold mountains. Ex: Nappe.

6.7. 2. On the basis of affectness of denudational forces:

1. **Young fold mountains:** Which are least affected by denudation agents.
2. **Mature Fold Mountains:** They consist of Monoclonal ridges and valleys.

6.7.3. On the basis of period of origin:

1. **Old fold mountains:** During the Caledonian and Hercynian periods, these have been eroded and became residual mountains today. Ex: Aravallis mountain of India.
2. **New folded mountains:** These mountains are formed in the tertiary period (60 to 75 million years ago). Ex: the Himalayas, Rockies, Andes, Alps, and others. These are also known as Young fold mountains.

6.8: CHARACTERISTIC FEATURES OF FOLDED MOUNTAINS

- These are formed by intense horizontal (lateral) compression.
- The rock strata are folded and forms low-angle thrust faults.
- These are formed in a long, narrow, and shallow sea called Geosynclines.
- All young fold mountain consists of sedimentary rocks. These rocks are very thick (thousands of meters).
- Marine sediments are commonly found.
- These mountains are long and shorter in width. Ex: the Himalayas are 2400 km in length and 400 km in width.
- These are in Arc shape. One side of the mountain has a concave slope, and the other side convex slope.
- Along these mountains, Batholiths are generally found.
- Valuable minerals like gold, silver, tungsten, and others are found in fault regions.
- Rocks were metamorphosed due to intense heat and pressure.
- Folding is more in the central parts of the mountain and less in the margins.
- The fold mountain belts are irregular, and generally, they are curved.
- These mountains are generally located along the margins of the continents. Ex: Andes of South America, Rockies of North America, etc.,
- The highest peak of the world, Mt. Everest (8848 meters), is located in young fold mountain (Himalaya).

6.9: STAGES OF MOUNTAIN BUILDING

Folded mountains take a long duration to form. We can identify three important stages of mountain formation. They are-

1. Geosynclinal Stage
2. Orogenic Stage
3. Epeirogenic Stage

6.10: CONCEPT OF GEOSYNCLINE AND ITS DEVELOPMENT

The concept of Geosyncline was propounded by James Hall and Dana in 1859. This concept has been further enlarged by Haug. It is a long, narrow ocean basin in which deposition of sediments has been found. Geosyncline is a large depression, hundreds of miles long and tens of miles wide, in which many thousands of feet of sediments accumulated' (Marland P.Billings, Structural Geology).

According to Dana (1873), A Geosyncline is 'a long-elongated belt of long-continued subsidence and sedimentation. Compression, folding, and upliftment of this sedimentary strata leads to the formation of folded mountains from this ocean basin. For deposition of sediments in oceanic troughs, folding and upliftment of these strata require a long period of time. Denudational processes operating in either side of the landmasses provide essential sediments to Geosynclines. Ex: Appalachian Geosynclines in North America, Tethys Sea in Asia, Caledonian Geosyncline in the United Kingdom.

6.11: CHARACTERISTICS OF GEOSYNCLINES

- These are long, narrow, and shallow depressions of water.
- Continuous sedimentation and subsidence are common.
- Due to Geological processes and earth movements, the shape, size, location, and extent
  of geosynclines will change in the different time periods.
- These are mobile zones of water.
- On either side of Geosynclines, two rigid masses are commonly found. These masses are known as Forelands.

Based on the size, location, and evolution of Geosynclines, Schuchert has classified Geosynclines into three types. They are –

6.11.1. Mono Geosynclines: It is a long, narrow, and shallow water tract. These are passed through only one sedimentary cycle. Hence these are known as Mono Geosynclines. It is identified by Hall and Dana. Ex: Appalachian Geosyncline. These are generally located within the continent or along the borders of the continent.

6.11.2. Poly Geosynclines: These are larger and older than Mono Geosynclines. These were formed more than one phase of orogenesis and Geanticlines. A Genticline is an area from which sediments are derived and deposited in the Geosyncline. These were formed in a complex evolutionary process. Ex: Rocky and Ural Geosynclines.

6.11.3. Meso Geosynclines: These are very long, narrow, and mobile in nature. These are the most complex in nature and crossed several stages of Geosynclines. These are generally surrounded by continental blocks. Ex: Alpine, Himalayan mountains, Tethys Geosynclines, etc.,

ArthurHolmes (1957) has also classified the Geosynclines into four types based on their origin. They are –

1. Due to the migration of magma, Geosynclines were formed.
2. Metamorphism also causes Geosyncline.
3. Compression leads to the formation of Geosynclines.
4. Geosynclines are formed due to the reduction of the thickness of the Sial layer.

H.Stille (1935-50) has classified the earth's crust into two types. They are –

1. Cratons (Two types – Continental crust and Oceanic crust)
2. Ortho-Geosynclines (Main Geosynclines and Smaller Geosynclines)

In relation to plate tectonics, Geosynclines were classified into three types. They are-

6.12.1. Pacific type Geosynclines: These are found on converging plate boundaries. They are subdivided into two. They are –

a. Andes type – Oceanic trench located close to the continent.
b. Island Arc - Here, the trench is parallel to the arc, but it is away from it.

6.12.2. Atlantic type – Here, deposited sediments take place on the edge of the continents.

6.12.3. Mediterranean type – It is found in the convergence of plate boundaries and in the sea located between two continents.

Phases of Mountain Building or Stage of Geosynclines

6.13. The formation of a folded mountain from a Geosyncline needs a long period of time. There are three stages of the mountain-building process. They are –

1. Period of Lithogenesis
2. Period of Orogenesis
3. The period of Glyptogenesis

6.13.1.The period of Lithogenesis: It is the beginning of mountain building. In this stage, sedimentary rocks are formed and lead to the formation of mountains. Sediments were deposited in the Geosynclines. At the same time, subsidence will take place. This process is known as Sedimentation-subsidence. Due to this, there is compression from both sides, which further induces subsidence as the two sides of the geosyncline come close together. This process is known as compression-subsidence.

6.13.2. Period of Orogenesis: In this stage, the pressure further increases in Geosynclines. Huge compression leads to produce folds. The process of thrust faulting and recumbent folding further increases the thickness of the sediments. After the folding and faulting, the uplifting of the region starts. The horizontal compression and vertical uplift are distinct processes in mountain building, and the vertical uplift of the mountain begins.

6.13.3. Period of Glyptogenesis: In this phase, there is a steady rise of mountains, and the agents of denudation start to wear away these landforms. Geosynclines will disappear in this stage.

6.14: HINTERLAND AND FORELAND

During the Mesozoic era (nearly 240 to 63 million years), there was a very large Geosyncline called as Tethys Sea. It was located at Alpine and Himalayan region of these days. This Geosyncline was extended for about 3000 km from North to South Gibraltar to the west to the East Indies in the East. Towards the north of Tethys Sea, the continental block is called Laurasia, and towards the south of this sea, the continental block is known as Gondwana land. Sediments started to deposit in this huge Geosyncline (Tethys Sea) during Carboniferous Period (360 to 299 million years). In the Cretaceous period (138 million years ago), Laurasia and Gondwana continental blocks started to move towards each other due to earth movements. According to Suess, the southern continental block (Africa) was pushing towards the north, which has been called 'Backland' (Hinterland). The stagnant continental block in the north (Laurasia) has been considered as Foreland. Argand has also supported the views of Suess.

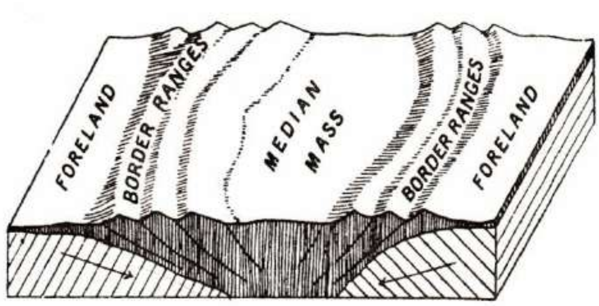
6.15: Orogenic Stage

Geosynclines are not stable or constant. In a long period of time, sedimentation, subsidence, and compression will occur in these Geosynclines. It leads to the formation of mountains. Here orogeny means ‘mountain building activity. Suess, Hang, Argund, and J.W.Ewans states that folds are formed due to compression (→←) of these Geosynclines. There are several views of scholars regarding the origin of folded mountains. They are –

1. Geosynclinal – Orogen theory of Kober.
2. Thermal Contraction theory of Jeffreys.
3. Radio-activity theory of Joly
4. Daly’s Hypothesis of Slinding Continents.
5. Convection current theory of Arthur Holmes.
6. Plate tectonic theory.

6.15.1. Geosynclinal-Orogen Theory of Kober: The famous German Geologist Kober has postulated this theory. According to him there are two forelands instead of one foreland and a hinterland and they are overthrusting each other. According to him, due to compression of Geosynclinbes along the margins of foreland of ancient landmasses mountains were formed. He called this ancient landmass as ‘KRATOGEN’ and border ranges as ‘RANDKATTEN’. The area located in between the two border ranges is not affected by folding. This region has been called ‘ZWISCHENGEBIRGE’ or Median mass by Kober. Ex: Alpid in the north and Dinarid in the south of Alps Mountain, Tibet plateau between the Himalayas and Kunlun, etc.,

Figure: 6.1



Formation of an Orogen resulting from the mutual approach of two rigid masses

The shape and size of the median mass depend on the relative magnitude of the two under thrusts. He also tried to explain the evolution of continents and oceans. He states that the ancient rigid landmasses provide the foundations for the present continents. The area of these rigid masses has increased due to the accumulation of sediments in Geosynclines and the formation of mountains from these.

Kober has propounded the contraction (shrinking) hypothesis. According to him, the contraction of the earth was started from the beginning of the earth. He identified six major periods of mountain building in the geological history of the earth. Among these, three have been found in the Pre-Cambrian era (4600-542 million years ago), and the remaining three have occurred in Post Cambrian period.

When mountains were uplifted, agents of denudation starts to wear away the mountains, and these were reduced by depositing sediments in Geosynclines. There is a long gap between one orogeny to another.

He also explained another type of movement of the rigid landmass or KRATOGEN. He called this as Kratogenic movement. These movements are responsible for the formation of rifts and fractures in the landmasses. It may cause the folding of the sediments along the margins of landmasses in the regions of the transgressional sea. Ex: Rift valley of East Africa, Block mountains of Central Europe, Jura Mountains, etc.,

The location of rigid landmasses determines the direction and location of mountains. The area of Europe has enlarged by the addition of folded zones in different geological periods to the rigid Russian landmass. Suess was the first to propound this view, and H.Stille supported this.

Kober accepts the theory of Isostasy. He believed that contraction is the basic force for compressional stress. He accepted that the bottom of high mountains consists of low density of rocks. In different geological periods, there is a constant conflict between horizontal and vertical forces. Hence uplift and sinking are alternatively taking place in this zone.

6.15.1.1. Critics:

i. The force of contraction, as stated by Kober, is not sufficient for the formation of the Alps, Himalayas, Andes, Rockies, and others.
ii. His assumption is that two forelands move towards each other and compressive forces are responsible for folding. It has not been accepted by several scholars. According to Suess, one side of the Geosyncline moves, and the other side remains constant.
iii. He explained the origin of the West to Eastward trend of mountains and but not North-South extending mountains (Ex: the Rockies, Andes, etc.,).

Even though there are few critics, his theory throws light on the formation of mountains from Geosyncline sediments.

6.16: THERMAL CONTRACTION THEORY OF JEFFREYS

H.Jeffrey has propounded Thermal contraction theory in his book "The Earth; Its Origin, History and Physical Constitution" (1929). According to him, cooling of the earth due to loss of heat and decrease of the speed of rotation is the cause of contraction.

According to him, there has been no change in temperature below 700 km from the earth's surface up to the centre of the earth. But the temperature decreased in the upper layer of the earth rapidly compared to its lower layer. Hence the top layer had more contracted than its lower layer. To adjust with its slowly cooling layer, the upper layer starts to compress, which produces folding and faulting. The shrinking lower crustal layer becomes smaller than the hot interior and does not fit with the upper layer. It creates tension and leads to the formation of fissures and cracks. These were filled with hot magma from the interior. The intermediate zone is between the upper zone of compression and the lower zone of tension. This intermediate zone is known as the 'Level of no strain.' As the cooling of the earth continues, this intermediate zone (Level of no strain) starts to slide downwards from the surface of the earth. The horizontal compressive force leads to the formation of folded mountains.

When the stress is more than the strength of the rock, earth movement starts and leads to mountain building. It continues till stress and pressure reduce. At that time, there is a slow or stop of mountain building activities (quiet period). During this period, stress starts to accumulate and leads to more pressure again. He states that the cooling of the crust is more under the oceans compared to under the landmasses. The rocks under the ocean floor are strong and heavy basic rocks compared to the rocks under the landmass. Hence, he assumes that the compressive forces generated under the ocean move toward the continental landmass and vice-versa. Ex: Circum-Pacific mountains. But he fails to explain the process of Alps and Himalayan Mountain formation, which are in different directions. He also states that when the pressure on the lower layer increases, the melting of the lower layer uplifts the mountains. He opposed the views of Wegner regarding continental drift. The contraction of the earth is not only from the loss of heat but also from the crystallization of rocks. When 500^0C of temperature decreased in 400 km of the upper layer of the earth, it will be 130km of the circumference of the earth. If contraction, crystallization, and loss of gases were also included, nearly 200 km of the circumference of the earth would be reduced.

6.16.1. Critics: His theory has been criticized on several backgrounds. The most important are-

i. The cooling of the earth, which results in the force of contraction, is not sufficient for the origin of major relief features of the earth, according to Arthur Holmes.

ii. J.A.Steers has criticized the impact of the decrease in the speed of the rotation of the earth over mountain building.

iii. If the earth was contracted from all sides, there should be equal distribution of continents and oceans. But at present, there is an uneven distribution of these. According to this theory, mountains may be formed everywhere due to all parts of the earth's crust experienced contraction. But we found that mountains are present along the margins of the continents, either north-south or west-east.

iv. The concept of cooling of the earth in the form of concentric layers is not accepted.

v. Due to thermal contraction, there may be a possibility of minor folds and wrinkles. But not to the extent of huge mountains like the Alps, Rockies, Andes, Himalayas, etc.,

vi. At the same time, Kober has not given a proper explanation for the formation of the Alps and the Himalayas.

6.17: RADIO-ACTIVITY THEORY OF JOLY

Radio-activity theory has been propounded by J.Joly, and his views were published in his book 'The Surface History of the Earth (1925)'. His theory is also known as 'Thermal Cycle Theory' or 'Theory of the surface of the Earth.' He tries to explain the formation of mountains in his book. He accepted the concept of Isostasy, and the continental masses are consisting lighter materials compared to the bottom of the oceans. The lighter Sial (2.67 - Granite) lies on heavier Sima (3.0 – Basalt). According to Isostasy, any mass above the denser sima must be compensated to a proportion. It means that eight times of Sial has been submerged under sima. Based on the mean height of the continents above the substratum and taking buoyancy effects of the oceans, Joly calculated that the Sial mass is about 30km thick and under the mountains is proportionally more.

The most important factor of this theory is the radioactivity of the rocks. To some extent, all rocks are radioactive and producing heat by a continuous and automatic breakdown of certain elements like uranium and thorium. The rocks in Sial are more radioactive than sima. The release of heat in this process is very little, but in a long span of time, the accumulation of heat may be great and sufficient to produce considerable changes in the interior of the earth.

According to him, the heat lost by the radiation from the earth's surface is more than the heat received by radioactivity. In this condition, the heat released by radioactivity is preserved in the sima. After a long period of time, the accumulated heat is enough to melt the basalt. But under the ocean floor, the heat from sima has been lost by conductivity. He assumes that below the 30 km thickness of Sial, the temperature should be 1050^0C. But the melting point of Basalt is 1150^0C. So, to melt substratum or Sima, the temperature should increase by 100^0 C. By Mathematical calculations, he tried to show that it will take another 33 to 56 million years for the heat accumulated due to Radioactivity to melt the Basaltic Rocks.

When the substratum becomes liquid, then its density reduces, and the continents start to sink further down into the Sima due to their lightness. Hence the water from the oceans will flood towards the margin of the continental masses. It is known as the Transgressional Sea. In this condition, a huge number of sediments were deposited in the shallow coastal regions of the Transgressional Sea. In this way, he tries to explain the formation of Geosynclines and after folded and uplifted as mountain chains. At the same time, due to tension on the ocean floor (due to the absence of a thin layer of Sial), fissures take place, and molten magma comes out, forming islands. All these processes are very slow and take millions of years.

In the molten stage of the Substratum, the tidal effect will cause the westward movement of Sial masses, leads to the escape of heat. He assumed that the heat would escape almost entirely from the ocean floor. The reduction of temperature will lead to the solidification of the substratum. The upper parts of this layer cool first, and then the lower parts, which are still in the liquid. Due to various reasons, large blocks of the cooled surface were broken and sank to molten Sima due to their high density. So complete resolidification will take place from below upwards. Hence the earth's radius will decrease again to normal leads to the continents will be moving towards the earth's center. The newly solidified sima has a greater density, so the continental mass will rise to the upper level of sima. Due to this Transgressional Sea will disappear. There will be a fall in sea level. It is known as the **'Regressional Sea.'**

The contracting ocean floor creates great pressure on continents, which will be compressed between oceans. The soft sediments which were deposited in Transgressional seas will be strongly folded due to lateral pressure. It is the first step in the formation of mountains. After the folding, there is a rise of mountain mass due to Isostatic balance. It is the second stage of mountain formation. The complete period between the two solid stages of the Sima is called a Revolution. The time required to melt Sima will be assumed between 33 to 60 million years. Based on this, Joly advocated that mountain building activity is cyclic and regularly repeating.

6.17.1. Critics: Several scholars have criticized Joly's theory. They are-

i. Joly has assumed that the thickness of Sial is 30 km. But based on Seismological evidences, Jeffrey criticized this, and according to him, the thickness of Sial is about 16km.

ii. Based on some mathematical laws, Jeffrey stated that when Sima has melted under the influence of Radio-activity, it cannot resolidify.

iii. This theory is based on the radio-active elements in the rocks. But even today, we have only very less information about the interior of the earth.

iv. The time interval between mountain buildings, as stated by Joly, is doubtful.

v. Joly's view on Geosynclines is not accepted.

vi. The margins of the continent must have mountains of the same period. This view has not been accepted by several scholars.

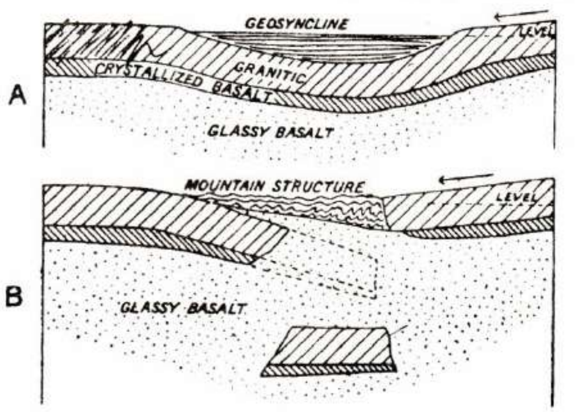
Even though there are several critics regarding this theory, it sheds light on only mountain-building activities.

6.18: THE HYPOTHESIS OF SLIDING CONTINENTS BY DALY

Daly postulated his sliding continents hypothesis in his book 'Our Mobile Earth' (1926). His theory is based on Gravity. He made certain assumptions to develop his hypothesis. He assumed that the distribution of land and water masses was determined in the early days. These rigid landmasses are located near the poles or the equator. Between these three rigid masses, the low-lying areas are occupied by sea. He considered these as 'Mid-latitude Ferrows.' In the northern hemisphere, the Tethys Sea was considered a mid-latitude ferrow, but little information about the southern hemisphere. He considered the Pacific Ocean as gigantic. The land bodies are higher than the sea and sloped towards the Pacific Ocean and the middle-latitude ferrows. In these depressions, sediments were deposited by the agents of denudation.

There was a slow loss of heat from the interior of the earth to the outer parts. The interior layer shrunk compared to the outer layer. So, the outer layer collapsed due to the weight of ocean and water and the weight of the sediments in Geosynclines. The downward pressure has caused lateral pressure. Due to this, the extent and height of the continental masses have been increased. Excessive strain (pressure) in Geosynclines has caused the rupture. So large continental blocks start to slides slowly toward Geosyncline and cause squeezing and folding of sediments caused the first stage in mountain formation.

Figure 6.2



(A) & (B) Crumpling of Geosynclinal prisms of layered rocks by the sliding of a large block of the earth's crust

Daly has assumed that the substratum consists of hot glassy basalt, which is 'Slippery'. The density of the substratum is less than the outer crust. When rupture takes place in the crust, they were pushed down and sank in the substratum. The sediments in Geosynclines are less dense than the substratum; they will not sink into it. Hence there were squeezed and further pushed down and melted. It expands and rises. It is the second phase of mountain building.

Due to the shrinking of the globe, the speed of rotation of the earth further reduces. It helps in the development of the crust in the globe. The sliding of continents takes place on an unlevel surface in early times. According to him, Geosynclinal sediments were responsible for folding and lateral pressure exerted by the sliding of continents towards the Geosynclinal sea. On this basis, the Alps-Himalayas (west-east) mountains were formed. Due to the sliding of continents towards the Middle-latitude ferrow, Rocky and Andes mountains from north to south were formed by sliding of continental blocks toward the Pacific Ocean. Island Arcs and islands in East Asia were formed by the sliding of the Asiatic landmass toward the Pacific Ocean.

6.18.1. Critics: There are several criticisms of this theory. The most important are-

i. His theory is mostly based on certain assumptions, which are guesses in nature.

ii. The structure of the crust is different from Jeffrey, who classified it based on Seismic evidences.

iii. His concept regarding Geosynclines is confusing.

iv. According to him, the Substratum is less dense than the upper crust, which is difficult to accept.

v. He has not given an answer to the question of how Pangaea is divided into three parts due to sliding, and two depressions were formed between them.

vi. Wooldrige and Morgan have stated that ‘the cause of the primary bulges which start the slipping has not been satisfactorily explained.

Even though Daly’s theory has critics, but it is very useful and sheds light on various aspects of the formation of the mountain.

6.19: CONVECTION CURRENT THEORY OF ARTHUR HOLMES

Arthur Holmes has postulated the current convection theory in 1928-29. The main aim of his theory is to explain the processes of mountain formation. But it also describes volcanicity associated with mountain building and continental drift. This theory tries to integrate the divergent views on mountain building and continental drift.

He explained the internal structure of the earth. The upper layer of the interior of the earth is called Crust. The lower part of the crust consists of crystalline rocks. Below this layer, it is called a Substratum which is fluid or glassy in nature. Below the ocean floor, the upper part of the sialic layer does not exist. It is very thin. This theory is based on convection current in the substratum, which depends on the Radioactivity of the rocks.

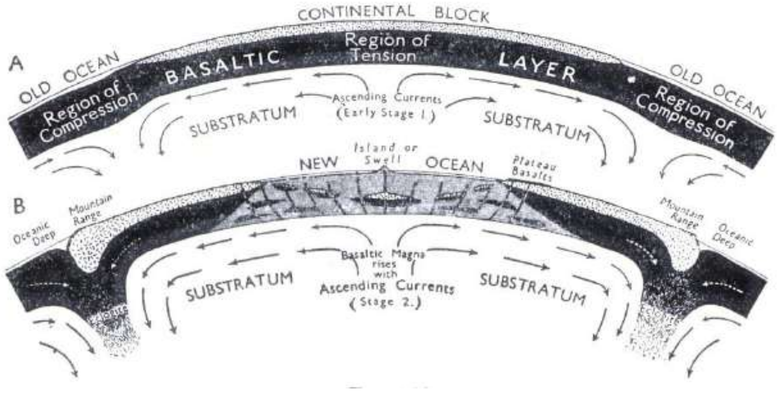
He estimated that the average amount of heat lost per annum by radiation into space and conduction to the surface is about 60 calories per square cm. The radioactivity is concentrated in the upper layers of the surface of the earth. He claims that the convective currents are possible within the substratum. It also depends on the radioactive elements in the crust to counterbalance the annual heat lost by conduction to the surface. The circulation of Convective current will depend on –

The thickness of the substratum varies from the equator towards pole. Near the equator, the thickness of the crust is more than the polar areas. Due to this, the temperature gradient in the equatorial region is more compared to polar regions. Hence the convection current ascends near the equator and descends near poles. So, there is a greater movement in the lower layers of the crust than in the upper layers. It creates tension in the upper layers. The original equatorial landmass was broken by these currents into two. One part has moved towards the north and another towards the south. Between these two, Tethys Sea was formed.

The radioactive substances are more in Continental Crust than the oceanic crust. Due to this, the temperature is more under the continental crust, and convection currents are active and powerful. The convection currents under the continent’s caries more molten materials upward and then turn toward the oceans. But under the oceanic crust, the convection currents are weak. They meet the powerful currents under the continents on the continental margins in the continental shelves and descend. The convectional currents do not originate in one place but at several places. Their origin place keeps on changing. It is periodic in nature.

The currents flowing horizontally below the crust inevitably carry the continents along with them. The basaltic layer which obstructs this movement will be moved away to deeper parts, as shown in figure-6.3

Figure: 6.3



Convectional Currents

When two opposing currents come together and turn downwards below the basaltic rocks, it leads to intense compression. The downward movement of the basaltic layer would be an ocean deep. The great deeps bordering the festoon islands of Asia and the Australian are probably represent that the Sialic edge of a continent has turned down to form the inner flanks, while the oceanic floor creates the outer flanks. Here the currents descend, subsidence will take place, and Geosynclines were formed. Deposition of sediments takes place in Geosynclines and creates the conditions for mountain building. He identified three stages in which Geosynclines were formed, folding and upliftment of mountain take place.

The first stage is of long duration. The convection currents are strong, converge and descend near the continental shelves. It forms Geosynclines; sedimentation will take place and due to subsidence of Geosynclines occur. In the zone of the descending currents, the roots of the mountains are formed by the subsidence of Geosynclines. It is the preliminary stage of the mountain building.

In the second stage, the convection currents become faster. But this stage is relatively shorter. The convection currents from the continental and oceanic crusts descend downwards with huge force, resulting in maximum compression occurs in the Geosynclinal sediments causing folds. In this way, the mountain-building process starts.

In the last stage, the convection currents become weak. The velocity and pressure of descending currents reduce. Due to this, the folded sediments start to uplift. The heavier materials start to ascend. In this stage, the mountains are uplifted, and it continues till the Isostatic balance occurs.

In 1939 Griggs tried to prove the validity of the current convection theory of mountain building. He confirmed the cyclic arrangements of the convection currents through an experiment. Based on his results, he propounded Tactogene or the Root theory of mountains.

Holmes also explained the drifting of Continents and the formation of Oceans. At the same time, he pointed out the origin of the Alps-Himalayan range, North American Cordillera, Island groups of East Asia. Along the margins of Lauratia, Andes, mountains are formed on the margins of Gondwana land.

6.19.1. Critics:

i. The knowledge regarding the behavior and existence of convection currents are extremely limited.

ii. We do not know that the convection currents are so powerful to break up and drifting of continents.

iii. Several scientists have questioned the high temperature in substratum generated by radioactive elements.

iv. The rising and falling of blocks are doubtful.

v. Holmes has not answered that why convectional currents are not originated at all places?

Even though this theory has several critics, but it received support and confirmation from the study of Plate tectonics.

6.20: PLATE TECTONICS AND MOUNTAIN BUILDING

We have already discussed Plate tectonics in chapter number 3. Geoscientists divide the outer part of the earth into two layers. They are -Lithosphere (consist of Crust and top portion of the upper mantle), which is rigid in nature. The lithosphere floats on a relatively soft or plastic layer called Asthenosphere.

The Lithosphere is a rigid cover or shell of the earth. It consists of a number of major breaks, which separate it into distinct pieces called 'Lithosphere Plates' or 'Plates.' The breaks between plates are known as Plate boundaries.

In other words, a plate boundary is a place where two plates meet together. These plate boundaries are generally associated with major geological events like – Earthquakes, the Creation of mountains, Volcanoes, Mid-Oceanic ridges, and Oceanic Trenches. The plates are floating over the Asthenosphere. Sometimes plates collide with each other or pull apart or slide each other. The plate boundaries are named in different names based on their relationship with each other. Depending on the nature of plate interactions, three types of plate boundaries are identified. They are-

1. Divergent Plate boundaries.
2. Convergent Plate boundaries.
3. Transform Plate boundaries.

6.20.1. Divergent Plate Boundaries: When two adjacent oceanic plates move apart in opposite directions due to seafloor spreading. It forms a new crust due to the intrusion of magma. The youngest oceanic crust has been formed by this. So, these are also known as constructive plate boundaries. Oceanic ridges and rift valleys are formed by this kind of Plate boundaries. They do not show uniforms spreading everywhere. Fault planes separate the adjacent ridge blocks due to differences in spreading rates. Geologists think that a mid-ocean ridge will develop.

6.20.2. Convergent Plate boundaries: When two plates collide with each other, it is known as convergent plate boundaries. Convergence of Plate boundaries takes place in three situations. They are-

a. Continent – Ocean Plate Collision
b. Continent – Continent Collision
c. Ocean – Ocean Plates Collision

6.20.2.a. Continent – Ocean Plate Collision: It is a common type of collision. When continent-ocean plates converge, it results in Cordillera type of folded mountains. Ex: the Rockies and Andes Mountain. The oceanic plate is heavier; hence it moves down under the continental plate in the trenches. Geologists refer to the sinking process as Subduction. Hence Convergent plate boundaries are also known as Subduction Zones. One thrust block overrides the other, which is also known as Obduction. The sinking plate is melted in the Benioff zone, and some magma was intruded, and some have erupted on the surface as Andesite magma. The downward movement of the plate is recorded by a series of earthquake waves in the Benioff zone, where the focus is about 300 or 400 km depth, or it may be more. In the early Mesozoic era, Andes Mountain was formed. The oceanic plate subdues under the South American plate. As the oceanic plate moves down further under the South American plate, the pressure further increases, the orogenic has intensified.

6.20.2.b. Continent – Continent Collision: When two continental plates colliding each other, the zone of collision is called as 'Suture Zone.' It means that where two plates are sutured or stitched together. It is easy to identify the Suture zones by observing the remnants of the Oceanic crust.

Himalaya was formed by the collision of the Indian Plate with the Tibetan block of the Asian Plate. Between Indus and Tsangpo rivers, the Suture zone was found where we observe the remains of the extinct of Tethys Ocean floor.

When two Plate boundaries converge from the subduction zone, there was a release of high silica basalts along the continental margins or over the Island-Arc zones. Here high silica basalt was formed by mixing of granite type of continental rocks during the ascent of mafic magma through it. Like this, African and European plates were collided to form the Alps in southern Europe and Atlas Mountain in north-west Africa.

6.20.2.c. Ocean – Ocean Plates Collision: When two oceanic plates start to converge, one of the crusts of the oceanic crust of the oceanic plate moves downward under the other oceanic plate in trenches, leads to compression leads to the formation of Island Festoons and Island Arcs. These types of mountains are common along the western coast of the Pacific and the northeast coast of the Indian ocean.

Converging movements cause geological effects. The most important are-

- ❖ It may result in down-wrapping of the crust, Geosynclines, or Linear basins may be formed.
- ❖ The deformation of the crust resulting from the compression.
- ❖ The heat is produced by the metamorphic and magmatic activity.
- ❖ Upliftment of mountains.

6.21: EPIEROGENIC STAGE

There is a relationship between the formation of mountains and continental building. Due to compressive force, up wrapping and down wrapping takes place. Due to this, a compressive force may uplift (fold) the mountains. Agents of denudation will wear away these and deposit the sediments. So new mountains will be formed.

6.22: LET US SUM UP

In this unit, we have discussed the diastrophic forces and their types. We came to know that there are several theories regarding mountain building. Each theory has its own views and explains the formation of mountains. Plate tectonic theory is the recent theory which also describes the formation of mountains in the world.

6.23: KEYWORDS

Diastrophic force, Epierogenic movement, Orogenic movement, Mountain ridge, Mountain Chain, Cordillera, Residual Mountain, Geosynclines, Hinterland and Foreland, Radioactivity, Substratum.

6.24: QUESTIONS FOR SELF-STUDY

1. What is a Mountain? Explain the different types of Mountains.
2. Explain the phases of Mountain Building.
3. What is a Geosyncline? Explain the characteristics and different types of Geosynclines.
4. Explain the Geosynclinal-Orogen theory of Kober.
5. Explain the Radio-activity theory of Joly about mountain building.
6. Explain Arther Holmes's theory of Mountain building.
7. Critically examine Plate Tectonic theory and Mountain building.

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UNIT – 7

VULCANACITY: TYPES AND DISTRIBUTION

Structure:

7.0: INTRODUCTION

Volcanism is another important internal force operating on the earth. It shows the dynamic activity of the earth. The landforms created by volcanism are modified by the agents of denudation. In recent years, the development of new techniques has greatly helped to study volcanoes and their landforms. Volcanic activity is greatly responsible for the creation of the atmosphere and hydrosphere on our planet.

7.1: MEANING

The term volcano has been derived from the island Vulcano (near Sicily), which means burning mountain from the Latin 'Vulcanus or Volcanus'. Vulcan was the Roman god of metal working. The word Volcano was first applied to Mt.Etna by the Romans. It was considered the place of God. A volcano is a conical or dome-shaped hill or mountain formed by the extrusion of lava or any other Pyroclastic materials from a vent.

According to Philip.G.Worcester (1965), 'Volcanism includes all phenomena connected with the movement of heated material from the interior or toward the surface of the earth.'

A.Holmes and D.L.Homes (1978) define as 'A volcano is essentially a fissure or vent communicating with the interior from which lava flows, fountains of incandescent spray or explosive bursts of gases and volcanic ashes are erupted at the surface.'

Dayal P (1995) states that Volcano is 'A deep vent in the earth's crust through which molten rocks or hot lava, ash and hot gases are ejected from the earth's interior to the surface of the earth.'

Volcanoes are defined as the openings of any shape or size which act as a place for the magma to rise and spread upon the earth's surface in the form of lava flows. Volcanoes are probably as old as the earth. Magma has erupted through the weak regions in the crust. A volcano is considered one of the most significant landform created by volcanism.

Volcanism means 'All the phenomena related to the eruption of magma to the surface of the earth. It gives the most important evidence of the dynamic nature of the earth. The scientific study of the volcano is known as Volcanology.

7.2: STRUCTURE OF A VOLCANO

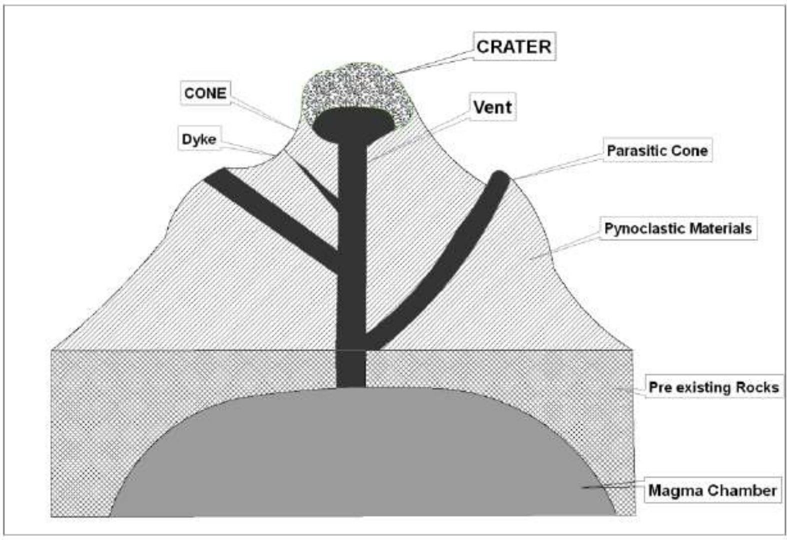
A volcano is a circular opening or a vent through which several materials from the inside of the earth were ejected to the surface of the earth. The major parts of a Volcano are

7.2 1. Crater: A funnel or cup-shaped depression of the top of a volcanic cone is known as a crater.

7.2 2. Vent or Pipe: The crater is connected with the magma chamber inside the earth through a pipe-like conduit is known as a Volcanic Pipe or Vent.

7.2 3. Cone: The ejected magma rushing out of the vent creates a cone-like formation in the upper part of the vent is known as a cone. Sometimes it looks like a mountain. Large-sized craters are called Caldera.

Figure: 7.0



Structure of a Volcano

7.3: VOLCANIC PRODUCTS OR MATERIALS

Ejection of several materials from the interior of the earth is known as 'Volcanic Eruption.' These materials are solid, liquid, and gaseous. Steam and various gases are released from the volcanoes. 60 to 90% of these are water vapor. Carbon dioxide, Sulphur dioxide, Hydrogen, Nitrogen, Phosphorous, Argon, and other gases are released.

The volcanoes releasing Sulphur vapors are known as 'Solfataras.' When Carbon dioxide is released, they are called 'Mofettes.' When Boric acid vapors are released, they are termed as 'Saffioni.' The consolidated volcanic ash is called 'Tuff.'

A huge quantity of solid materials was thrown out by a volcano. The solid rock pieces of different sizes erupted by a volcano are called Pyroclasts or Tephra. According to their size and shape, they are called in different names. The largest angular masses of rock pieces are known as 'Blocks' or 'Brescia.' These are the huge solid fragment ejected during volcanic activity. When molten lava is thrown out into the atmosphere, before reaching the surface, it cools down, solidifies to round, oval, or pear-shaped forms. These solid rounded materials are called 'Volcanic Bombs.' If they are small as peas, they are known as 'Lapilli.' If they are in the form of solid rocks, they are known as 'Cinders' or 'Pumice' or 'Scoriae.' When the volcanic materials range in size from 0.25mm to 4mm, these fine particles are known as 'Volcanic ash.' The minute Pyroclastic materials, which have less than 0.25mm, are known as Volcanic dust or Fine ash. The rock, which is composed of a mixture of ash, dust, Lapilli, and cinder, is called Volcanic Tuff. When the Volcanic bombs are predominant in the tuffs, they are referred to as volcanic agglomerates. The welded tuffs are commonly known as 'Iguimbrites.'

Lava is the major and important liquid product of a volcano. The molten rock materials under the surface are known as 'magma.' The magma that has flows out of a volcano over the surface is called Lava. The temperature of lava is usually ranging between 900^0 C to 1200^0 C. The character of lava mostly reflects its viscosity. Viscosity means resistance to flow. Differences in viscosity depend on a variety of factors like chemical composition, temperature, gas content, and crystal content. Andesitic lava has a greater viscosity than Basaltic lava. Depending on Silica content, magma or lava has been classified into two types. They are –

7.3.1. Acidic Lava or Magma: It consists more amount of more Silica and a high degree of melting point. It is viscous in nature. It cools very slowly and consists of many gases. Ex: Rhyolites.

7.3.2. Basic Lava or Magma: It consists of less than 50% amount of Silica. It has a low degree of melting point and has high density. It cools quickly. It spreads to larger areas forming flows or sheets. The best example of basic lava is Basalt.

Based on their chemical composition, lava acts differently and gives rise to different configurations when consolidated. The most important are-

7.4.1. Lava Tunnels: When the lava cools in the outer surface, it forms a crust. Sometimes it is still in the liquid inside the crust. It may come out in weak places forming a tunnel. It is known as Lava tunnels.

7.4.2. Block Lava: It consists of little gas and flows slowly. While flowing, bubbles are formed due to the escape of gases and cools quickly. It is also known as 'aa-lava'.

7.4.3. Ropy Lava: When lava cools slowly and spreads to a larger area due to low viscosity. It forms like a thin sheet with a smooth surface that wrinkles or twisted. It is also known as the Pahoehoe structure. It is generally found on the ocean floor.

7.4.4. Pillow Lava: When lava erupted under waterlogging conditions, it comes out as a pile of rounded blocks or pillows.

7.5: CAUSES OF VOLCANISM

There are several causes for volcanic activities. It is related to theoretical geology, which deals with the interior of the earth. The most important causes of volcanoes are –

7.5.1. High temperature and pressure: As depth increases from the surface, the temperature also increases. Roughly at 68km depth, all most all solid particles are melted, and they are in the liquid state. Due to the very high temperature, it melts the surrounding rocks and expands its area. So the solid crust will become thinner, and at some time, the magma comes out from this thin layer.

7.5.2. Radioactivity: High temperature within the earth is due to the disintegration of radioactive minerals and the production of heat. Chemical reactions within the earth and friction due to the earth's movements also may produce heat.

7.5.3. Crustal deformation: When folds, faults are formed, cracks or fissures will develop, through which magma comes out.

7.5.4. Seafloor spreading: When two plates move in the opposite direction (divergent), fissures will form, and from this, magma comes outside. When continental plates converge, the high density of oceanic plates subsides under continental plates of low density. Trenches are formed due to this. From this, magma comes outside, and it forms Island Arc.

7.5.5. Water: The water on the surface of the earth moves inside the earth through cracks and fissures. When it gets contact with molten magma, it is dissolved or evaporated. Due to high temperature, it is converted into stream. It escapes from the cavities, through which magma comes out.

7.6. TYPE OF VOLCANOES:

Volcanoes are classified into several types based on mode and periodicity of eruptions. They are –

7.6.1. Based on Mode of eruption:

7.6.1.**a. Central or Explosive eruption:**

i. Hawaiian Type
ii. Strombolian type
iii. Vulcanian type
iv. Vesuvian type
v. Plinian type
vi. Pelean type

7.6.1.b. Fissure or Quiet eruption:

i. Lava flood or lava flow
ii. Mud flow
iii. Fumaroles.

7.6.2. Based on the periodicity of eruption:

a. Active Volcanoes
b. Dormant Volcanoes
c. Extinct Volcanoes.

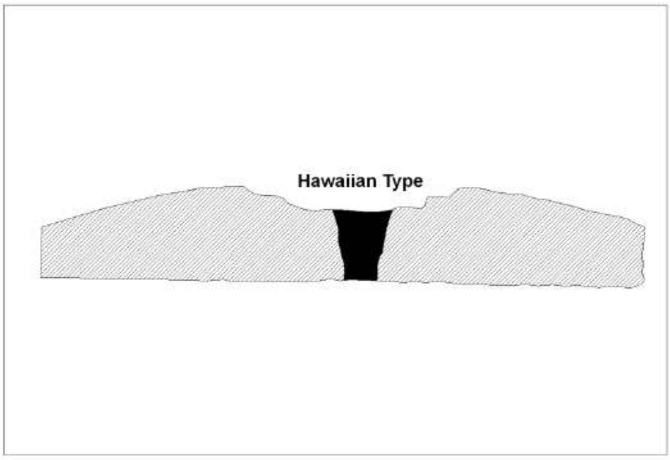
7.6.2.1.Based on the mode of eruption:

7.6.2.1.a. **Central or Explosive eruption:** In this type, the volcanoes consist of a bowl-like depression called a crater and a vent or pipe connecting crater with magma-chamber through which the volcanic materials reach the surface of the earth. Ex: Cotopaxi Volcano in Ecuador. Sometimes, there may be other subsidiary holes along the slope of hills through which magma and other materials are released. Ex: Etna Volcano.

The nature and intensity of eruption depend on the viscosity of magma and the pressure of gases. When magma is basic (basalt), which is less viscous, the eruption is quiet or peaceful. If the magma is acidic, i.e., more viscous, the eruption is more explosive. At the same time, the number of gases, magma, and their pressure determines whether the eruption is peaceful or not. Based on the chemical composition of the lava, gases, and the nature of the volcanic structure, central eruption volcanoes are further classified as-

7.6.2.1.a.**i. Hawaiian type:** There is a release of magma slowly or silently without any explosion in this type. Lava flows like a river along the slopes of a mountain. Lava is basaltic. Sometimes lava is associated with gases ejected to the air and solidified in the form of long glassy threads known as 'Pele's Hair.' It is the characteristic feature of the Hawaiian islands of the Pacific Ocean. Hence these are known as the Hawaiian type as shown in figure 7.1. Ex: Mauna Loa and Kilauea volcanoes in the Hawaiian Islands.

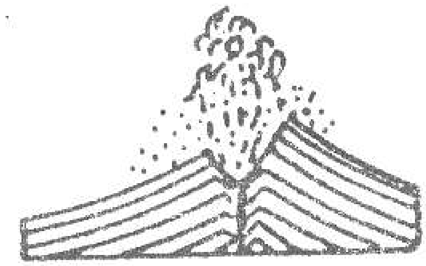
Figure:7.1



7.6.2.1.a.**ii. Strombolian type:** In this type, the eruptions will occur every 10 to 15 minutes. The explosion is very mild. The periodic ejecting magma will not allow the cooling of magma. This type is named 'Stramboli,' a volcano found in the Mediterranean Sea. At nights, the ejection of lava is seen as the red glow of the fountain to faraway places, especially for navigators. Hence it is known as 'Light House of Mediterranean'. Ex: Helka Volcano in Iceland.

Figure:7.2

Strambolian type volcano

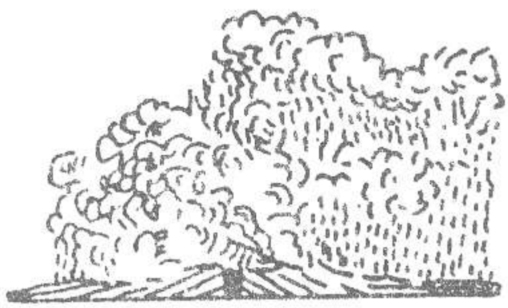


7.6.2.1.a.**iii. Vulcanian type:** Here, the interval between eruptions is more. Lava is more viscous in nature; hence it solidifies between continuous eruptions and causes explosions. It releases more ash. It is named after 'Vulcano' in the Lipari Islands of North Sicily, which shows this kind of eruption. Here magma is more viscous in nature.

Figure: 7.3
Vulcanian type volcano

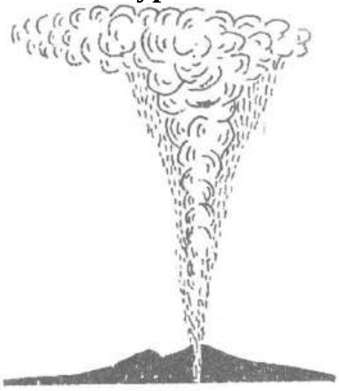
7.6.2.1.a**. iv.Vesuvian type:** Here, there is a violent eruption of magma due to the intensity of the gases, and the magma comes out with great force. The eruptions occur after long intervals. Volcanic ashes, Lapilli, Volcanic bombs, etc., are comes out from these. The gases will form cauliflower-like clouds. This type of eruption was recorded by Pliny in A.D.79, which occurred at Vesuvius. It is located in the Mediterranean region. Due to this, the name has been given to this type.

Figure: 7.4
Vesuvian type Volcano



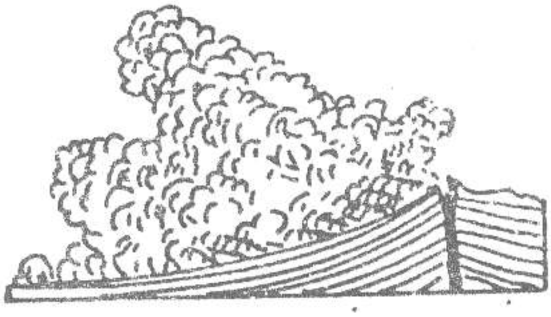
7.6.2.1.a.v. **Plinian type:** It is a more violent type of Central eruption. In the last phase, there is an uprush of gas that carries clouds rapidly upward in a vertical column for kilometers. It is narrow at the base but expands outward at higher altitudes. Tephra is less in these clouds. There is very little discharge of lava.

Figure: 7.5
Plinian type Volcano



7.6.2.1.a vi. Pelean Type: It is the most violent explosive type of volcano of all types. The lava is of andesite composition, highly saturated with gases, and extremely viscous. At the time of the eruption, the dense magma solidifies and closes the mouth of the crater before flowing along with the dome. Due to excessive pressure inside, a huge explosion takes place due to gases. After this, hot magma, pieces of materials, and ash flow along the slopes of domes like an avalanche. It is known as ‘NueesArdentes’ or ‘Glowing clouds. The clouds are illuminated by the burning of gases. The town of St. Pierre at the foot of Mont Pele’s was destroyed by this kind of volcano in 1902. It is exhibited by Mont Pele’s located on the island of Martinique in the West Indies. In 1883, Krakatoa (Java-Indonesia) eruption, more than 1/3 of a cubic mile of the old cone was thrown out. In 1911, Mt.Taal in Philippine Islands violently erupted. Part of the old crater walls was blown away, and a new inner crater was formed.

Figure: 7.6
Plean type Volcano



7.7. Fissure or Quiet eruption: Along the fracture zones, this type of volcano is formed. Here, there is a slow rising of magma from the interior, and the lava spread over the ground surface. In this type, lava is basaltic type(thin) and flows to all areas. Ex: 1783, Laki eruption in Iceland, Travera eruption in New Zealand in 1886, etc.,

Figure: 7.7

In this type, volcanic cones are not formed. Lava that comes out from these fissures spread to a larger area forming lava sheets. The Deccan traps in India are made up of basaltic lava flows.

Fumaroles are the openings in the earth through which gases and water vapor through the vent is known as 'Fumaroles.' It is the last sign of active volcanoes. Several fumaroles are found in groups near Katmai Volcano of Alaska. It is found in an extensive valley which is known as 'A valley of ten thousand Smokes.' These are found along a linear fracture. Carbon Dioxide, Hydrochloric acid, Hydrogen Sulphide, Nitrogen, Ammonia are released by these. If it releases more Sulphur, these are known as **'Solfatara.'** Some volcanoes release carbon dioxide; these are called Mhofettas. Mudflows occur in the early stages of eruption. The dust ejected from the Vent mixes with condensed. It carries these fragmented materials to faraway places.

7.8: ON THE BASIS OF PERIODICITY OF ERUPTION

Based on the periodicity of eruption, volcanoes are classified into three types. They are;

1.Active Volcanoes 2.Dormant Volcanoes 3.Extinct Volcanoes

7.8.1.Active Volcanoes: The volcanoes which erupt periodically are called Active Volcanoes. Ex: Mt. Vesuvius in Italy, Mono Loa in Hawaii Islands, Cotopaxi of Andes mountain in South America, Etna in Sicily, etc. Barren Island of Andaman and Nicobar Islands in India is an active volcano. There are nearly 500 active volcanoes in the world.

7.8.2. Dormant volcanoes: The volcano which has not been erupted for a long time but is expected to be active at any time is called a dormant volcano. These kinds of volcanoes are also known as sleeping volcanoes. Ex: Vesuvius volcano (Italy), Mountain Kilimanjaro in Tanzania (Africa), Fujiyama of Japan, Krakatoa of Indonesia is some examples of a dormant volcano.

7.8.3.Extinct volcanoes: Some volcanoes have not erupted for a long time. They are not likely to erupt in the future. These are known as Extinct volcanoes or Dead volcanoes. Ex: Volcanoes of the Eiffel district of western parts of Germany, Auvergne in Central France, Popa mountains in Myanmar, etc., several extinct volcanoes are also found in Mauritius Malagasy and several islands in the Indian Ocean.

We should remember that it is difficult to classify the volcanoes as Active, Dormant, and Extinct. Because at any time, the Dormant Volcano may become active.

7.9: VOLCANIC TOPOGRAPHY

The topography of volcanoes is likely to change in each eruption, especially in explosive types like Vulcanian and Peleean types. High-perfect cones are very rare. Most volcanic mountains on the earth were formed a very long ago. Cones and mounds of these were attacked by various agents of gradation. Active and Dormant Volcanoes are found in the form of chains in Aleutian, Hawaiian and Japanese islands. One of the most remarkable groups of volcanoes is found in Ecuador (South America), where 22 great volcanic mountains are found. Among these, 15 are more than 15000 feet in height, with Cotopaxi (19613 meters) one of the highest active volcanoes in the world. Various types of topographical features were formed by volcanic activities over the surface and under the surface.

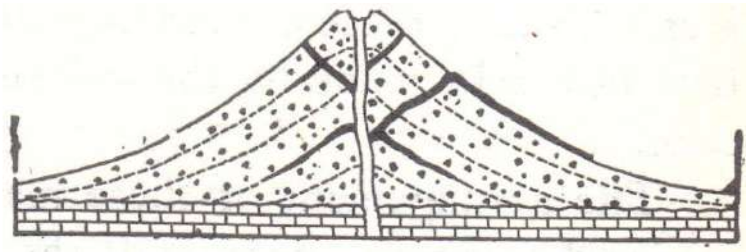
The major elevated topographical feature produced by the volcanoes of Central eruptions is –

1. Composite Cones
2. Cinder or Ash Cones
3. Spatter Cones
4. Shield Volcano (Exogenous / Shield domes)
5. Acid lava cones
6. Lava domes / Mounds
7. Lava Cinder and Ash plains
8. Parasite cones
9. Mud Flows
10. Lava plugs, Spines
11. Cliffs and Crags etc.,

7.9.1. Composite Cone: The volcanic materials like lava, ash, and other materials which are deposited one after the other in parallel layers form a composite cone as shown in figure 7.8. The lava which flows and cools like sheets strengthen the cone, and rock pieces that are thrown away from the crater construct these cones. The rock pieces of all sizes, from dust to huge blocks, lie on slopes whose angle is about 35^0 to horizontal plane. At higher angles, the rocks tend to roll down the slopes. Generally, these are cut by dykes formed by the solidification of lava in cracks or fissures during the volcanic explosions on the sides of the cone. The transported materials along the slopes of these cones are eroded easily. The cones of these volcanoes are higher than the others. These are also known as ‘Strato cones’. Most of the largest, highest, and most symmetrical volcanic mountains of the world belong to this type. Ex: Shasta, Hood, Rainier of Western USA, Mayon in Philippine islands, and Fujiyama in Japan.

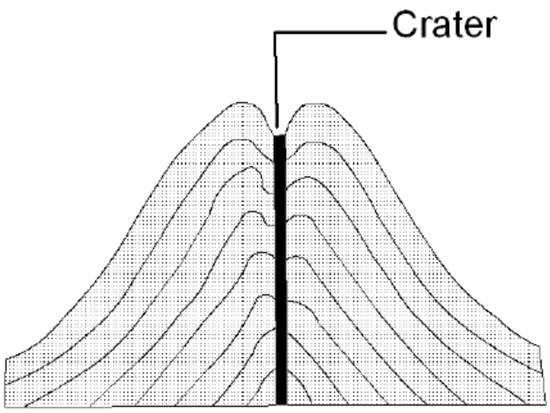
Figure: 7.8

Composite Volcanic Cone



7.9.2. Cinder or Ash Cones: It is a relatively low cone composed of fragments thrown out of vents by small explosive volcanoes. The loose, unconsolidated rock pieces lie on the outer slopes of the cone. In humid regions, the fine material is soon washed away from cinder cones, creating fans at the foot of the slopes. The original form of a cone is preserved by the resistance materials like coarse materials, bombs, scoria, etc.,

Figure: 7.9
Cinder Cone



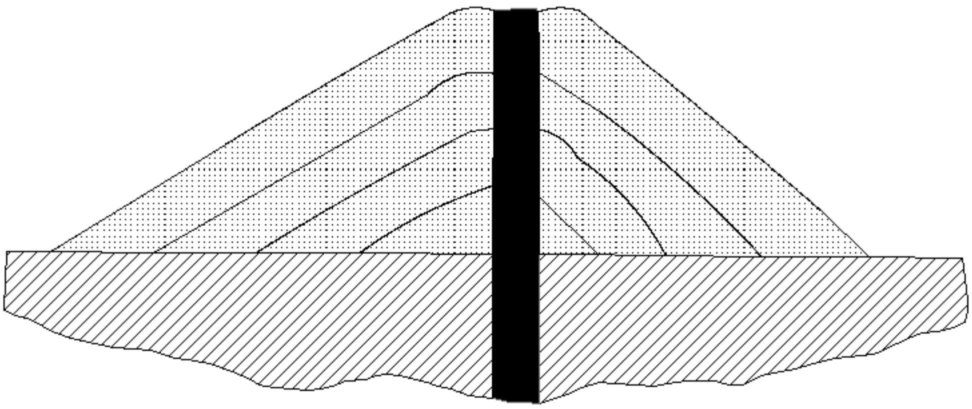
7.9.3. Spatter Cones: These are common in both central and fissure eruptions. These are formed by gas bubbles that accumulate and burst through the raising lava in small irregular cones. These small cones are also known as Spatter or Driblet Cones.

7.9.4. Shield Volcanoes / Shield Dome: These are formed by volcanoes that releases mainly lava from their craters or cracks in their sides. Lava flows up to the base of the mountain. Due to this, gentle slopes are formed in the mountains. This type of volcano is also known as an Exogenous dome. Ex: Hawaiian type.

Figure: 7.10
Shield Volcano

7.9.5. Acid Lava Cones: The viscous lava which is rich in silica forms acid lava cones. This kind of lava flows slowly and solidifies quickly. They are light-colored with low density. It forms high cones with steep slopes. These types of cones are also known as the 'Strombolian type of Cone.'

Figure: 7.11
Acid Lava Cone



7.9.6. Lava mounds or domes: These are formed around volcanic vents. They are steep-sided masses of lava that develop dome shape. It is formed by high viscous lava, which is rich in iron and magnesium. These lava domes are also known as 'Cumulo domes.' Howel Williams has classified these domes into three types. They are –

a. Plug domes
b. Endogenous domes
c. Exogenous domes / Shield domes.

7.9.6.a. Plug domes: It represents upheaval conduit fillings.

7.9.6.b. Endogenous domes: It has been developed within it. The surfaces of all domes of this type are fractured, and many have spines. After the lava cools and crusts over, it is broken by fresh rising magma from below. Through these cracks, gases and loose materials will come outside. Ex: Mt.Pele. These types of domes are found in France, South America, Greece, Mexico, Alaska, California, and others.

7.9.6.c. Exogenous domes: These are found over the surface. We have already discussed this type in Shield volcano or dome.

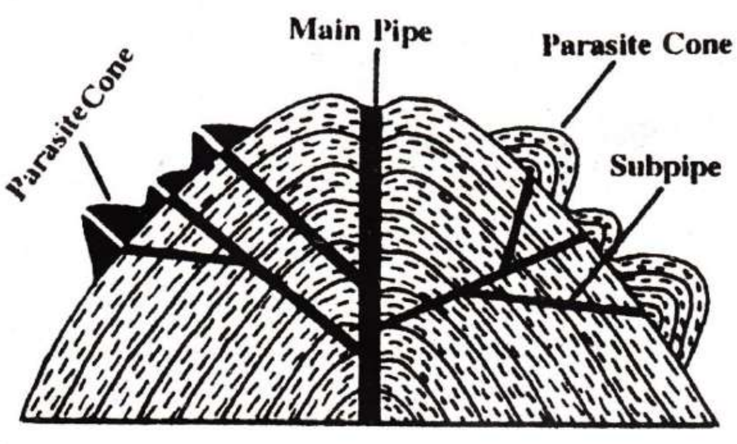
7.9.7. Lava Cinder and Ash plains: Several explosive volcanoes of the Central type releases dust and other pieces of material over larger areas. The fine dust (ash) and small pieces of materials may be deposited by the wind. Due to these, extensive plain areas were formed. This plain consists of dust, pumice, scoria, and breccias of several types. A continuous deposit one on the other (and the above) leads to cementation of the fragments by the minerals from groundwater forms a rough stratified structure.

Depending on the composition viscosity and gases of the lavas, any kind of surfaces are formed. Some are sponge-like structures, some rope like, corded surfaces are known as 'Pahoehoe' lavas. Some irregular surfaces are also formed, which are 'aa' type.

7.9.8. Parasite Cones: These are associated with Composite cones. In the explosion type, the top of the volcano has thrown out and forms a larger crater. Within this enlarged crater, a secondary cone may develop. These secondary cones are known as Parasite Cones. Ex: Etna in Sicily. Some volcanoes have several major cones, which are known as multiple volcanoes.

Figure: 7.12

Parasite Cone



7.9.9. Mudflows: It occurs in the beginning stages of violent explosions and continues till the eruptions are over. The dust which comes outside of the volcano mixes with steam, and rainwater frequently falls during an eruption. Due to this, Alluvial fans and plains are formed at the base of the volcanoes. Hence the course of the streams is blocked. Big boulders are carried by the mud too long distances. When lava flows over large snowfields on glaciers, a large quantity of water has been released. It flows along the sides of the mountain and carries the fragmented materials causing huge mudflows.

7.9.10. Lava plugs and spines: When composite volcanoes become extinct, their vents are caused by solidified lava. When the cones eroded, the more resistant plug is exposed. These plugs, which filled vents, pipes on necks, are sometimes called volcanic necks. Ex: The Devil's tower on Mato Tepee of Wyoming in the Black Will district.

When the old plug slowly rises by volcanic forces, it is known as the volcanic spine. Ex: Spine in Mount Pele (1902). Due to two great explosions in Lasen peak in California (1915), an old plug was lifted up to 300 feet.

7.9.11. Cliffs and crags: Great explosions and intense eruptions of Strombolian, Volcanic or pelean types, the mountain tops, the sides of cones, and old craters were destroyed. It was caused due to accumulation of lava and gases, cause this type of explosion.

7.10: DEPRESSED LANDFORMS

There are several depressed landforms were formed by central eruptions. The most important are

1. Craters
2. Nested craters
3. Adventive craters
4. Calderas
5. Volcanic Rents

7.10.1. Craters: It is a pit at the top of a volcanic cone. It is usually a funnel-shaped hollow at the top of the Volcanic Vent. As cones and mounds grow, there is a tendency for craters to widen at the top. The size of the craters varies from small to very large. Sometimes their diameter has several miles. Ex: The crater of Aniakchak, an extinct in Alaska, is about six miles in diameter with a height of 1200 to 3000 feet height.

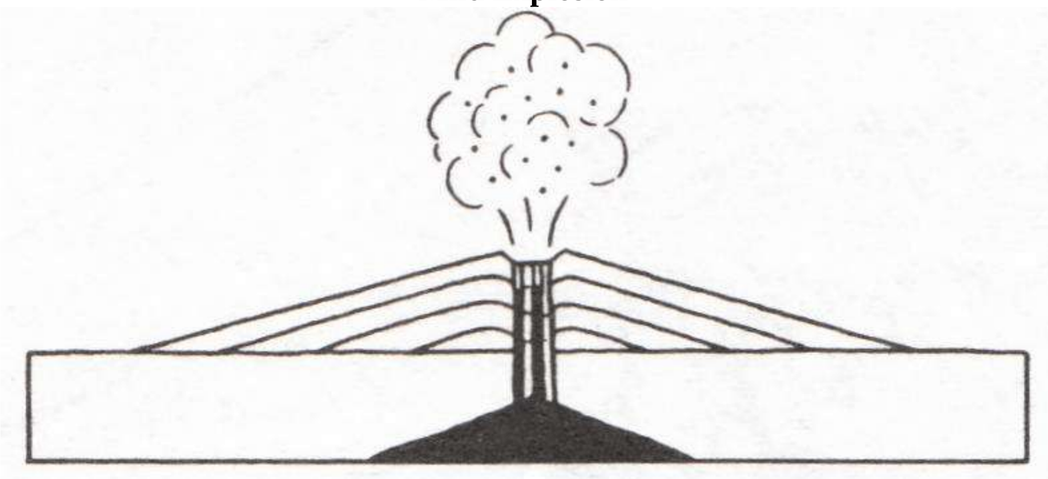
Sometimes pyroclastic materials are released by a volcano, and it accumulates around the opening (upper end of the vent). A ring-shaped mound is formed, which is known as the 'Crater ring.' Craters are located at the center of the ring. These craters are known as 'Ubehebes.'

Craters are also formed by Subsidence of the apex of the cone. In most cases, craters are formed by the explosion which occurs due to volcanic eruption. Here the top of the volcano is blown out of forming a crater.

In certain situations, small craters are formed without the building of cones. These small craters are called 'Explosion pits'. When these small craters are filled with water, they will become Crater-lakes. These are formed in Eifel district of Germany. They are known as 'Maare' or 'Maars.'

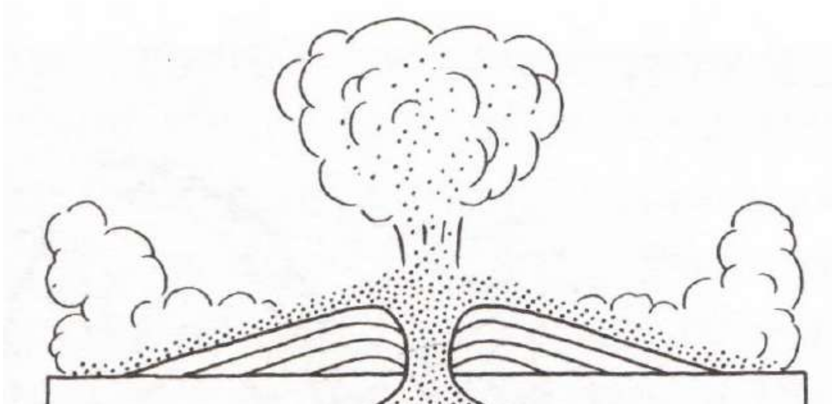
7.10.2. Caldera: It is an enlarged crater of several kilometers. These circular depressions commonly have steep inner walls and a flat floor. These are classified into different types based on their formation. They are-

Figure: 7.13
Mild Explosion



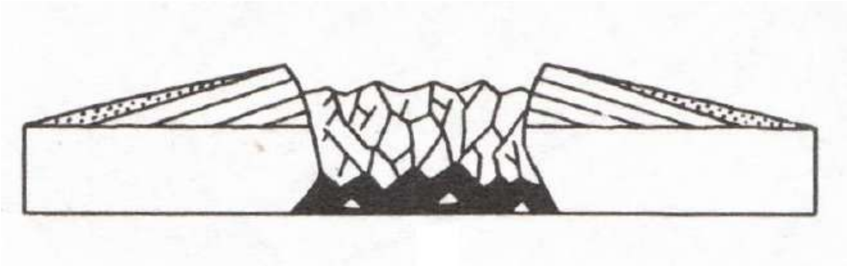
7.10.2.a. Explosion Calderas: When a violent volcanic explosion takes place, the central portion of the volcano was thrown out a huge central depression is formed. It is known as Explosion Caldera. Ex: Bandai-san in Japan.

Figure: 7.14
Violent Explosion



7.10.2.b. Collapse Caldera: When the top of a volcano collapses due to a fall of support in the bottom. Ex: Krakatau in Indonesia.

Figure: 7.15
Collapse Caldera



7.10.2.c. Resurgent Caldera: It is formed when the doming of the central block is collapsed. Ex: Valles Caldera in New Mexico.

7.10.2.d. Erosion Calderas: These are formed by the enlargement of craters or Calderas due to the processes of erosion.

Volcanic-tectonic depressions are similar to Caldera, but they occupy more area. Ex: Lake Toba, a volcanic depression in Indonesia.

7.10.3. Nested Craters: Several volcanoes have craters within craters. Ex: 3 craters are found in Mt.Taal in Philippine Island, Vesuvius, etc... These are called 'Nested Craters' or 'Cone-in-Cone.'

7.10.4. Adventive Craters: In old volcanic cones, small craters are found, and these are formed by the cracking of the older rocks. From these cracks, gases and lava come out to the surface with an explosion.

7.10.5. Volcanic Rents: Large irregular depressions in some cones or mounds due to explosion. These depressions are called Volcanic rents.

7.11: LANDFORMS FORMED BY FISSURE ERUPTIONS

The major landforms produced due to fissure eruptions are-

1. Lava Plains
2. Lava Plateau
3. Lava capped Mesas and Buttes
4. Rim Rocks
5. Volcanic Rifts.

7.11.1. Lava Plains: There is a little difference between lava plateau and lava plains in the thickness of the lava and in the depth of erosion. It consist of a single layer. Small rounded knolls (hills) are formed due to the escape of gases, bubbles, caves, glassy nature of the upper and lower surfaces of the individual flows are almost present.

7.11.2. Lava Plateau: From the fissures, the magma comes out and flows to surrounding regions. Continuous eruptions lead to the hundreds of feet thickness of lava, which solidifies, forming a plateau. Several ancient plateaux are formed in different parts of the world. Ex: Decan plateau of India, Columbia plateau of Western USA, etc., The thickness of the lava in this plateau varies from 2000 to 5000 feet. In this region, the fissure eruptions started in the Eocene epoch and frequently continued till the Pliocene period. During this period, 50,000 to 60,000 cubic miles of lava was released from the magma chamber. These plateaus are higher than 4000 feet from sea level. In many places, these lava places are folded and faulted. Parts have been uplifted, and large areas have been depressed. Some other lava plateau are- Iceland Plateau, Ivesti Mountains in East Africa, etc.,

7.11.3. Lava Capped Mesas and Buttes: In some places, lava flows from fissures over older rocks. After this, streams have cut valleys in this region. The land between the valleys is protected from erosion due to resistant layers of lava. Due to this, a single Mesa or Butte or a whole group of mesas and buttes are separated by river valleys of different depths. Ex: Southern Wyoming, Colorado, and New Mexico. Large Mesas are also called a plateau. Ex: Grand Mesa in West-Central Colorado, Raton Mesa is found between South-Eastern Colorado and New Mexico.

7.11.4. Rim Rocks: The sides of the vertical cliffs of Mesas are known as Rimrocks.

7.11.5. Volcanic Rifts: These are formed when fissure eruptions are explosive. Ex: In Iceland, the rift is about 18 miles long and 600 feet in depth.

7.12. INVERSION OF RELIEF

Frequent fissure eruptions construct huge plateau by lava floods, and it will cover the rifts and valleys and bring out changes in drainage courses. Streams are blocked so that lakes form in the valley above the lava dam. Continuous lava flow forms a layered structure. Ex: Auvergne region of France, Hassen in Germany, Western slopes of Sierra Nevada in California.

7.12. Intrusive topography: Before reaching the earth's surface, magma solidifies and forms various intrusive igneous rocks. The most important are – Batholiths, Laccoliths, Phacoliths, Lopoliths, Sills, and Dykes.

7.12.1. Batholiths: The term Batholith means 'deep rock.' These are very large intrusions of irregular shape, and their base is a great depth. The main characteristics of Batholiths are

a. The rocks are Plutonic. Most are composed of several Lithologic and textural varieties.

b. It covers an area of 100 km^2.

c. They commonly enlarge downward.

d. There is no visible floor; several geophysical evidences show that many Batholiths have floors at several miles of depth.

e. The roofs are irregular.

Generally, they are associated with mountain ranges. At the time of their formation, they were deeply buried. Continuous erosion has exposed these rocks. The surfaces of the batholiths are very irregular. Ex: Several Batholiths are found in parts of the Chotanagpur plateau of India. Smaller Batholiths are known as Stocks or Bosses.

7.12.2. Laccoliths: These are the intrusive body that has a dome shape. Ex: Henry Mountains of Utah, USA. They are generally 2 to 4 miles in diameter and a few thousand feet in thickness. Erosion may remove the sediments from the top of the intrusion, leaving highly inclined strata on the sides. These Laccolith rocks are found in the Western USA.

7.12.3. Phacoliths: These are intrusively confined to the crests of anticlines or to the troughs of Synclines. These are commonly associated with plunging folds. Their thickness varies from hundreds to thousands of feet. In layers of sedimentary rock strata, they are arranged one above the other between various layers of rocks.

7.12.4. Lopoliths: These are a large intrusion in a structural basin. It is bigger than sill and associated with a basin. These are arcuate or circular. Ex: Duluth Lopolith in Canada etc., These are saucer-shaped intrusions of large size which are concave upwards.

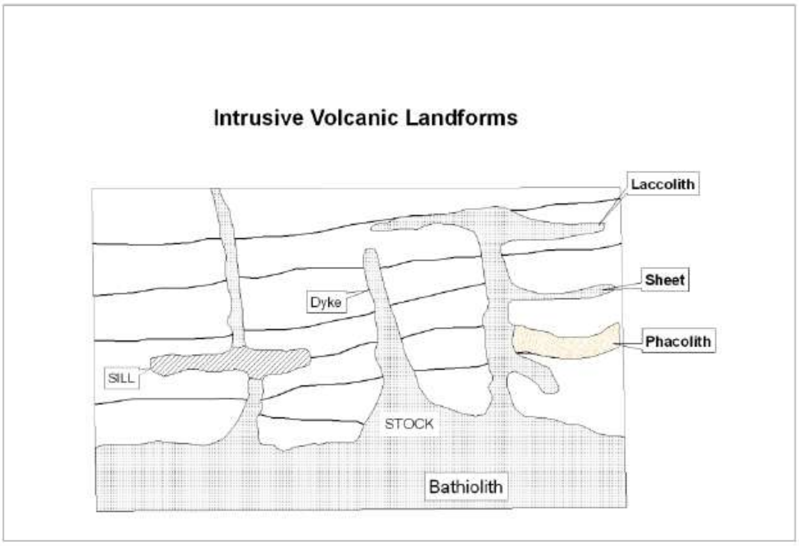
7.12.5. Sills: These are layer-like masses of igneous rock that have been forced between beds of sedimentary or metamorphic rocks. These rocks are parallel to the bedding of the adjacent rocks. Sills are younger than the rock on either side of it. Sills may be horizontal, Vertical, or Inclined. Thick intrusions are generally called Sills, and thin ones are known as Sheets. There are different types of Sills. They are – Simple Sill, Multiple Sill, Composite Sill, and Differentiated Sills.

7.12.6. Bysmaliths: It is a body of which the roof was uplifted along a circular or Arcuate fault. These intrusions have been described from the Black Hills of South Dakota of the USA.

7.12.7. Dyke: These are tabular bodies of igneous rock that cut across the structure of the older formations. They are formed by the intrusion of magma into joints, fractures, and fissures in the rocks. It solidifies there, only forming Dyke. They look like ridges. The

Great Dyke of Zimbabwe is the largest Dyke in the world. Simple, Multiple, Composite, and Differentiated dykes are the types of Dykes.

Figure: 7.16



7.13: VOLCANIC EXPLOSIVE INDEX (VEI)

A volcanic explosion generates long-lasting destruction in surrounding regions. To compare the volcanic explosions sometimes geologists, use the volcanic explosivity index, a logarithmic scale on which the largest known eruption has been assigned, a volcanic explosive index of 8. This index is based on the volume of debris ejected, the height of the eruptive column, and energy released during the explosion. Since 1800 AD, the historical record shows that there have been 100 eruptions with VEI in the range of 4 to 6. The largest observed eruption is recorded in history was Tambora in 1815, which ranks as a 7 of VEI. The geological record shows that a mega explosion with a VEI of 8 has taken place during the past few million years ago.

7.14: GEYSERS AND HOT SPRINGS

The term Geyser is derived from the Icelandic term ‘Geysir’ means gusher. Below the Geyser, there is a network of irregular cracks in very hot rock, which connects the ground surface. Groundwater sinks and fills these cracks and absorbs heat from the rocks. This heated groundwater begins to rise through a vent toward the surface. Some water is converted into steam. This steam quickly rises, ejecting all the water and steam above it out of the vent. Here hot water and steam are thrown at regular intervals from a fountain which is known as Geyser. Ex: Old faithful Geyser in Yellowstone National Park of the USA, where the hot water and steam is released every 60 minutes. These are also found in Iceland and Newzeland (Rotorua).

Hot springs release water of 30^0 C 104^0 C develops in two different geological settings. First, where groundwater slowly flows from the recharge area to the discharge area. The groundwater absorbs heat from the bedrock and carries it back up to the surface. Hot springs develop in geothermal regions, places where volcanism is currently taking place. In these places, magma or very hot rocks are found close to the earth's surface, and the shallow groundwater can become very hot. It comes out of the ground at a high temperature. The water released at hot springs can contain dissolved minerals. People will take mineral baths at some places. The minerals in hot water feed microbes, so natural pools of geothermal water may become colored. Ex: Yellowstone National Park, Wyoming.

7.15: EFFECTS OF VOLCANOES (HAZARDS)

The major hazards that occur due to volcanic eruptions are –

1. Threat of Lava flows.
2. Threat of falling ash and Lapilli.
3. Threat to aircraft.
4. Threat of blast
5. Landslides.
6. Threat of Lahars: Lahars are formed when volcanic ash and other debris mixes with water. This ash slurry resembles wet concrete. It flows at 50 km /hour through downslope. They left a gray and barren wake of mud, boulders, broken bridges and crumpled houses.
7. Threat of Earthquakes.
8. Causes Tsunamis.
9. Threat of Gas (Water vapour, Carbon dioxide, Sulphur dioxide, and hydrogen sulfide).
10. It destroys life and property.
11. Fertile soils are formed due to weathering of igneous rocks. Ex: Black soil.
12. Volcanic rocks consists several minerals. Ex: Conversion of Carbon into Diamond. Kimberley mine in South Africa.
13. The energy of the hot springs can be used to generate geothermal energy.

14. Several attractive landforms were formed by volcanic activities. Ex: Old faithful in Yellowstone National Park of USA.

7.16: WORLD DISTRIBUTION OF VOLCANOES

There is an estimate that there are not more than 800 volcanoes globally. Several extinct volcanoes can also be found in the world. The volcanoes are not evenly distributed in the world. Volcanoes are found in definite belts. These belts are associated with plate boundaries. There are three major volcanic belts. They are –

1. Circum-Pacific belt
2. Mid-Oceanic ridges.
3. Rift Valleys.

7.16.1. Circum-Pacific belt: It is a major volcanic zone in the world. It is found along the pacific coast, which encircles it on all sides in a semi-continuous belt. It is known as 'Ring of Fire or The Pacific Gridle'. It starts from the Andean region of South America, extends northward through Central America, Mexico, Western USA, Canada, and Alaska. Then it extends toward Aleutian Island, the Eastern coast of Asia, Kamchatka, Kurile Islands, Japan, Philippines, New Guinea, Solomon Islands, New Zealand, and Antarctica. This belt has 80% of the active volcanoes of the world. The major volcanoes of this region are – Cotapaxi, Fujiyama, Shasta, Rainer and Hood, Valley of ten thousand smokes in Alaska, Mt.St.Helens, Kilavea, Mt.Taal etc.,

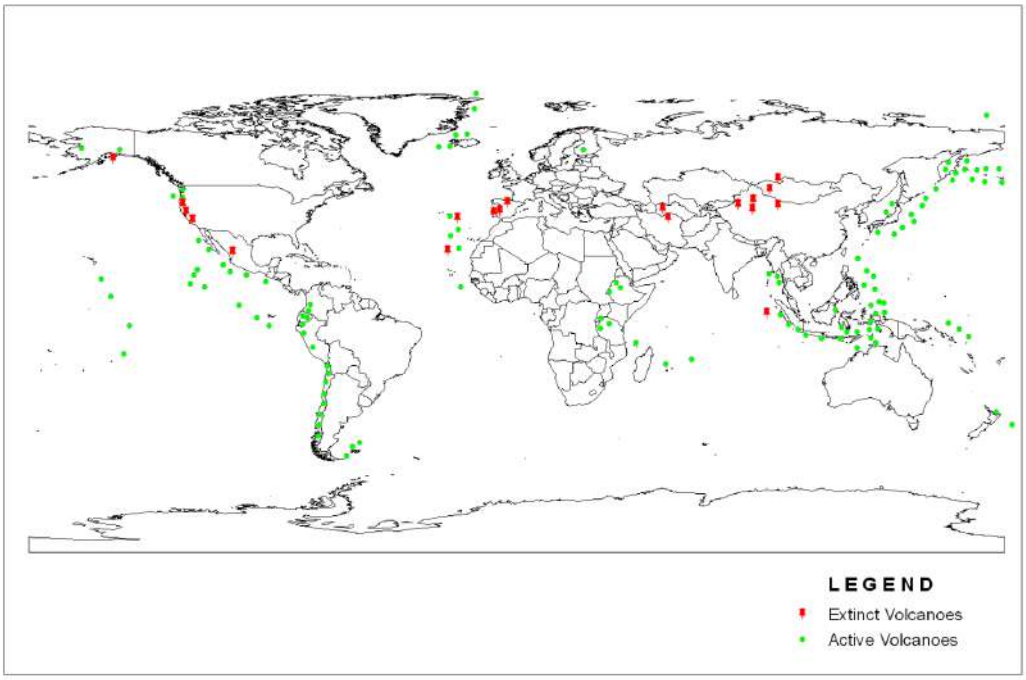
7.16.2. Mid-Continental belt: Only a few numbers of volcanoes are found at the Alpine-Himalayan Orogenic belt. Major volcanoes of this region are – Vesuvius, Etna, Stromboli etc., are the active volcanoes of the Mediterranean region. Towards the east of this, Caucasus, Elbruz mountain is found. The Alps and Himalayan areas are free from volcanoes.

Volcanoes are also found in the Rift valley. Kilimanjaro, Elgon, Birunga, Rungwe etc., and these are also found in the Rift valley of Africa.

7.16.3. Mid Atlantic Belt: Volcanoes are found along the Mid-Atlantic Ridge. American plate and Eurasian plates are moving apart (divergent). In this splitting zone, fissure eruption is common. Ex: Lesser Antilles, Azores, St.Helens etc., some volcanoes are also found in the inner parts of the continents. These are also known as Intraplate volcanoes.

In India, volcanoes are limited. Andaman-Nicobar islands are formed by volcanic activity. Barren and Narkodomn islands of this group consist of active volcanoes. Figure 7.17 shows the distribution of volcanoes in the world.

Figure 7.17
Distribution of Active and Extinct Volcanoes



7.17: LET US SUM UP

In this unit, you have studied one of sudden force operating on the earth. It is an endogenetic force, which is operating since the beginning of the earth. It is creating new landforms and modifying various types of landforms over the surface. It has some advantages and disadvantages for human beings.

7.18: KEYWORDS

Volcanism, Crater, Solfataras, Tephra, Brescia, Pumice, Ropy lava, Fumaroles, Ash cone, Parasite cone, Spines, Ubehebes, Buttes, Rimrocks, Sills, Volcanic explosive Index, Lahars.

7.19: QUESTIONS

1. Describe the causes of volcanoes.
2. Explain different kinds of volcanoes and their characteristics.
3. Explain the major landforms formed by the Central type of eruption.
4. Give an account of landforms produced by Fissure eruption.

5. Explain the distribution of volcanoes in the world.
6. Write short notes on:
    a. Composite volcanoes
    b. Geysers
    c. Hot springs
    d. Batholiths
    e. Dyke

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UNIT – 8

EARTHQUAKES: TYPES AND DISTRIBUTION

Structure:

8.0: OBJECTIVES

This unit provides you a basic knowledge about the earthquake. You will come to know that the causes of earthquakes, why and where it occurs? How can we measure the intensity of earthquakes? The effects of earthquakes and others.

8.1: INTRODUCTION

Earthquake is a natural hazard, which threatens human beings and their activities. Earthquake is one of the most horrifying natural calamities. Every year, thousands of earthquakes are occuring on the earth. Only a few earthquakes cause considerable damages to life and property every year.

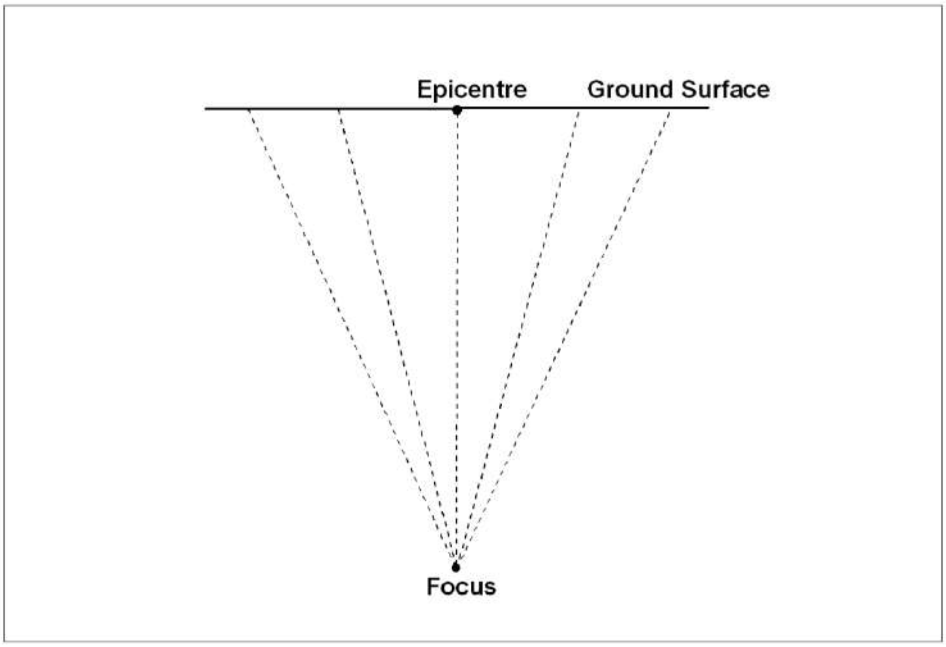
When a stone is thrown into a pond, a series of waves occurs in all directions. Like that, when rocks are suddenly disturbed, vibrations will spread in all directions. So, an earthquake is a vibration of the earth's surface due to a sudden release of energy stored under the surface.

An earthquake is a vibration or oscillation of the earth's surface caused by a transient disturbance of the elastic or gravitational equilibrium rocks at or beneath the surface (Macelwane J.B.1933). In other words, earthquake means 'tremors and vibrations in the crust of the earth'. Any sudden disturbance below the earth's surface may produce vibrations or shakings in the crust. Some of these vibrations reach the surface and are known as earthquakes. The scientific study of the earthquake is known as Seismology. It is derived from the Greek word 'Seismos' meaning earthquake. It is a branch of Geology.

8.2: FOCUS AND EPICENTRE

Earthquakes generally start below the earth's surface from a few km. The point within the earth where earthquake waves originate is called Focus or Seismic Focus, or Hypocentre. The point or place on the surface vertically above the Focus is known as Epicentre or Epicentral Line. Focus is a place where the earthquake waves reach first. It is the shortest distance between the focus and surface of the earth. At the epicenter, the intensity of the earthquake is maximum. But the extensive damage will occur where the earthquake waves reach the surface in oblique or slanting.

Figure: 8.0
Focus and Epicentre of the earthquake



The depth of focus may be from a few km to 700 km. Most of the earthquakes which have been recorded have their Foci (Focus) within 50 km. Only a few earthquakes that were recorded had their focus between 300 to 700 km.

8.3: EARTHQUAKE OR SEISMIC WAVES

The rocks which were under stress, the energy is released and sent out through the earth. These waves of energy are called Earthquake waves or Seismic waves. It originates in the focus of an earthquake and spreading in all directions. Earthquake waves are classified into three types based on their amplitude, wavelength, and nature of vibrations. They are –

1. Primary or Longitudinal or Compressional or Push and Pull waves or ‘P’ waves.
2. Secondary or Transverse or ‘S’ waves.
3. Surface or Rayleigh or Long or Love or ‘L’ waves.

8.3.1. Primary Waves: When rocks vibrate parallel to the direction of waves, it leads to longitudinal compression. It travels in solid, liquid, and gaseous matter. These are the fastest of all earthquake waves having an average velocity of 5.4 to 13.8 km per second. Due to their speed, it first arrives at Epicentre. The ‘P’ wave speed depends on the density and compressibility of solid, liquid, or gaseous particles. These waves travel faster in more rigid rocks than the other medium.

8.3.2. Secondary Waves: These are also known as Shear waves or Distortional waves. They vibrate at right angles to the direction of wave propagation. They are capable of changing the shape of the material without changing its volume. These waves cause shaking of the earth's surface hence it is known as shaking waves. These waves will not pass through liquids. The velocity of this wave is 3.2 to 7.2 km per second. It is more destructive than primary waves. Primary and Secondary waves are called body waves because; these are traveling deep into the body of the earth.

8.3.3. Surface or 'L' Waves: These waves are slower than 'P' and 'S' waves. They reach the surface of the earth at the end. These waves do not travel towards the interior of the earth from the point of origin of disturbance. These are confined to the outer part of the crust. Hence, they are known as Surface waves. These waves have a greater wavelength compared to 'P' and 'S' waves. Their speed decreases with an increase in depth. These are more destructive than any other earthquake waves. They cause huge damages to the lives and properties during the earthquake.

8.4: INTENSITY AND MAGNITUDE OF EARTHQUAKE

Several earthquakes occur every day in different parts of the world. Based on the number of recorded shocks during a year, on average, one earthquake will occur every two hours. A seismograph or Seismometer is an instrument that systematically records the vibration caused by an earthquake. The waves traced by a Seismograph are recorded over a graph known as Seismograph.

The lines joining the places where the shock arrives simultaneously are known as **Homoseismals** or **Conseismals,** or **Homoseists**. A line joining all the places having the same intensity of an earthquake is known as the **'Isoseismals line.'**

Some earthquake shakes the ground violently and causes extensive damages. Seismologists have developed to define size uniformly. From this, it is possible to compare earthquakes. Seismologists have developed two distinctive approaches to explain the relative size of earthquakes. They are – Intensity and Magnitude.

The intensity of an earthquake is a measure of the degree of damage and destruction caused by an earthquake. It can be observed without the help of an instrument. The intensity of an earthquake decreases outwards from the Epicentre. Generally, two scales of intensities are used to define it. They are –

1. Rossi-Forrel's Scale
2. Mercalli Scale.

In Rossi-Forrel's scale, the intensity has been classified into ten types. It starts from intensity number I, which represents the mildest earthquake, whereas intensity number X is the most disastrous.

In 1902, the Italian Scientist Giuseppe Mercalli developed the first widely used scale to express the size of an earthquake. This scale is known as the Mercalli Intensity scale. It defines the intensity of an earthquake by the amount of damage it causes. Now a day's Geologists are using modified Mercalli scale with Roman numerals. The higher the number of Intensity, the greater is the damage.

Table:8.0
Modified Mercalli Intensity Scale

Modified Mercalli Scale (MMI)	**Destructiveness (Perceptions of the extent of damage)**
I	Detected only by seismic instruments, causes no damage.
II	Felt by a few stationary people, especially in upper floor buildings, Lamps may swing.
III	Felt indoors,
IV	Shaking awakens some sleepers; dishes and windows rattle.
V	Most people awaken; some dishes and windows break, unstable objects tip over;
VI	Shaking frightens some people; plaster walls crack, heavy furniture moves slightly, few chimneys crack, overall little damage occurs.
VII	Most people are frightened and run outside; a lot of plaster cracks, unstable furniture overturns, poorly built buildings sustain considerable damage.
VIII	Many chimneys topple, heavy furniture overturns, substantial buildings sustain some damage, and poorly built buildings suffer severe damage.
IX	Frame buildings separate from their foundations; most buildings sustain damage, and some buildings collapse, cracks are found in the ground, underground pipes break and some landslides occur, damage for railway tracks
X	Most masonry structures and some well-built wooden structures are destroyed, severe cracks found in ground, many landslides occur along steep slopes, some bridges collapse, concrete dams may crack, railways and roads suffer severe damage.

XI	Few masonary buildings remain standing; bridges collapse; broad fissures form in the ground, most pipelines break, some dams collapse, most buildings collapse or are severely damaged.
XII	Earthquake waves cause visible undulations of the ground surface; objects are thrown up off the ground; there is a complete destruction of buildings and bridges of all types.

The sudden release of energy stored under the earth's surface causes an earthquake. This energy is released in the form of elastic seismic waves.

Magnitude is a measure of the energy released during an earthquake. A number indicates its relative size determined by measuring the maximum amplitude of ground motion recorded by a Seismograph. The amplitude of ground motion means the amount of up and down or back and forth motion of the ground. The larger the ground motion, the greater the deflection recorded in a seismograph.

Table:8.1

Richter Magnitude scale of earthquakes

Description	Richter Magnitudes	Earthquake effects
Micro	>2.0	Micro earthquakes, not felt
Minor	2.0 to 2.9	Generally not felt
Minor	3.0 to 3.9	Often felt, but rarely causes damage
Light	4.0 to 4.9	Shaking of indoor items, rattling noises, significant damage are unlikely
Moderate	5.0 to 5.9	Cause major localized damage to poorly constructed buildings; at most slight damage to well-designed buildings.
Strong	6.0 to 6.9	It can be destructive in areas up to about 100 miles across populated areas.
Major	7.0 to 7.9	Cause severe damage in areas several hundred miles across
Great	8.0 to 8.9	Cause serious damage in areas several hundred miles across
Great	9.0 to 9.9	Devastating in areas several thousand miles across
Great	>10	Never recorded

In 1935, American Seismologist Charles Richter developed the concept of defining and measuring the magnitude of an earthquake. It is known as Richter Scale (Table:8.1). A simple chart shows you to determine the magnitude if you know the amplitude of the largest deflection on a seismograph and the distance from the Epicentre. It is a numerical scale of magnitudes from '0' to '9'. The earthquakes measuring eight and above are considered

Catastrophic, which results in destruction. If it is '7' or above, the scale is called highly destructive.

Now a day, Seismologists are also using the moment magnitude scale, which gives the most accurate size of an earthquake.

All magnitude scales are logarithmic. It means that an increase in one unit of magnitude represents a tenfold increase in the maximum ground motion.

There are more than 600 stations in the world, which measures and records the intensity of earthquakes. In India, there are five stations where the intensity of earthquakes is recorded. They are – Kodiakanal (Tamilnadu), Poona and Kolba (Maharastra), Kolkatta (West Bengal) and Gowribidanur (Karnataka).

8.5: CAUSES OF EARTHQUAKES

Earthquakes are caused by a number of reasons. The most important are-

8.5.1. Surface causes: In the limestone region, the percolation of water continuously caused the falling off roofs. It causes minor earthquakes in that region. Landslides may also cause minor earthquakes.

8.5.2. Volcanic causes: The explosion of volcanoes leads to hydraulic shocks. Faulting within the volcano is also responsible for an earthquake. The collapse of the center of the volcano results in earthquakes. These earthquakes are localized and minor.

8.5.3. Tectonic causes: When crustal movements take place, earthquakes are caused. About 95% of all earthquakes in the world occur due to this. When there is an increase of stress, the rocks are forced fracturing with relative displacement giving rise to faults. The earthquakes caused by faulting or folding in the crust are known as tectonic earthquakes. Lines of fault in the crust are the areas where major earthquakes occurred. Ex: California Earthquake in 1906 etc.,

8.5.4. Disturbance of the crustal balance: The Isostatic balance between the depressed and elevated blocks is maintained. If there is any disturbance to this balance, earthquakes are caused. These are known as the tectonic origin.

8.5.5. Elasticity of Rocks: The elasticity of rocks is also responsible for the origin of earthquakes.

The margins or edges of the plates along which two neighboring plates are displaced are the regions of the tectonic earthquakes.

Prof. Reid H.F has postulated elastic Rebound theory to explain the origin of tectonic earthquakes. The earth's materials, being flexible, can sustain a certain amount of stress without permanent deformation. When the stress exceeds the elastic limit, a crack or fracture is developed. With increasing pressure on either side of the fracture, the rocks cannot hold more stress. At this point, there is a sudden slip of the fractured blocks to a position of no strain. The energy stored for hundreds of years is released suddenly, causing underground dislocation of rocks. It releases energy in the form of waves. The crack or fracture along which the displacements of rocks occur is known as a fault. According to this theory, earthquakes are most commonly associated with movement along a fault.

8.6: TYPES OF EARTHQUAKES

Earthquakes are usually classified based on the cause of origin, depth of focus, intensity, and magnitude of the earthquake. They are –

8.6.1. Tectonic Earthquakes: These are caused by the movement of crustal blocks or faulting. These are usually found at a depth of 3 to 15 miles from the surface. The intensity of waves varies from one to another. Gutenberg and Richter have classified the earthquakes based on the depth of their origin (focus) into three types. They are-

a. Shallow or Normal earthquakes: These are originating at a depth of fewer than 60 km.

b. Intermediate Earthquakes: They occur at a depth of 60 to 300 km from the surface.

c. Deep Earthquakes: They origin at a depth between 300 to 720 km from the surface. So far, no single earthquake with a focus beyond 700 km was recorded.

8.6.2. Plutonic Earthquakes: Generally, these earthquakes originate at a depth of 150 to 420 miles from the surface. Recrystallization of minerals, molecular changes in minerals, Chemical explosions, and others are possible causes of these earthquakes.

8.6.3. Non-tectonic Earthquakes: These earthquakes will occur due to volcanic eruptions, atomic explosions, landslides etc.,

8.7: EFFECTS OF EARTHQUAKES

There are several effects of earthquakes. The most important are-

a. Fissures or cracks are caused by earthquake waves. Ex: In 1967, the Koyna earthquake caused a fissure in the ground about 25 km long and 10 to 15cm in width.

b. There are several indirect effects of earthquakes. Ex: Landslides, bursting of dams, floods etc., In 1920, nearly two lakh people were killed in an earthquake at Loess highlands of China etc.,

c. Roads, Railways, and bridges were greatly damaged.

d. They also cause damage to water pipelines, telecommunication lines, and other underground pipelines.

e. Dams and Power stations were affected by earthquakes. Ex: On March 11 of 2011, an earthquake has occurred at Fukushima, which affected the nuclear power plant.

f. When strong earthquakes occur at the bottom of the sea causes huge and strong sea waves called Tsunamies (tsu means harbor, 'nami' means waves). They flow towards coast as a wall of water. It results in massive damage to life and property. In 2004, Tsunami in the Indian Ocean had killed more than two lakh people (from Indonesian islands to the East coast of Africa). In March 2011, a Tsunami occurred in Japan with 23 feet height of wave that killed more than 30,000 people. It happened at the Pacific coast of Tohoku with a magnitude of 9.0 has been officially termed as the 4th largest in the world since 1900 by Japan Meteorological Agency.

g. Severe earthquakes kill thousands of people and make more people homeless. Fires are also caused by earthquakes when there is a collapse of buildings. Ex: In 1906, an earthquake that occurred in San Francisco caused more damage by fires than by the earthquake itself. In 1923 fire had broken out by the earthquake devasted the cities of Tokyo and Yokoshima.

h. The earthquake in Japan (March 2011) shifts Honshu Island by 2.4 meters.

i. Underground water is also affected. Lakes and Swamps are created in many places.

8.8: ADVANTAGES OF EARTHQUAKES

There are certain benefits from earthquakes. It will create new waterfalls, streams etc., Shallow Sea areas may be uplifted to form new land. When subsidence takes place at the bottom of the sea, deep gulfs are created, which are most favorable for seaports. They also form springs, and sometimes dry lakes get water from these earthquakes, and valuable minerals may bring to the surface. It is possible to know the interior of the earth through these earthquakes.

8.9: DISTRIBUTION OF EARTHQUAKES

No place in the world is entirely free from earthquakes. Even the stable landmasses have experienced earthquakes. Ex: An earthquake occurred at Latur in Deccan Plateau. But all the regions will not experience the same intensity of earthquakes. Some regions will experience earthquakes frequently, and others are not. There are certain regions within the continents. It has been noticed that the most of the destructive earthquake originates in three belts. They are –

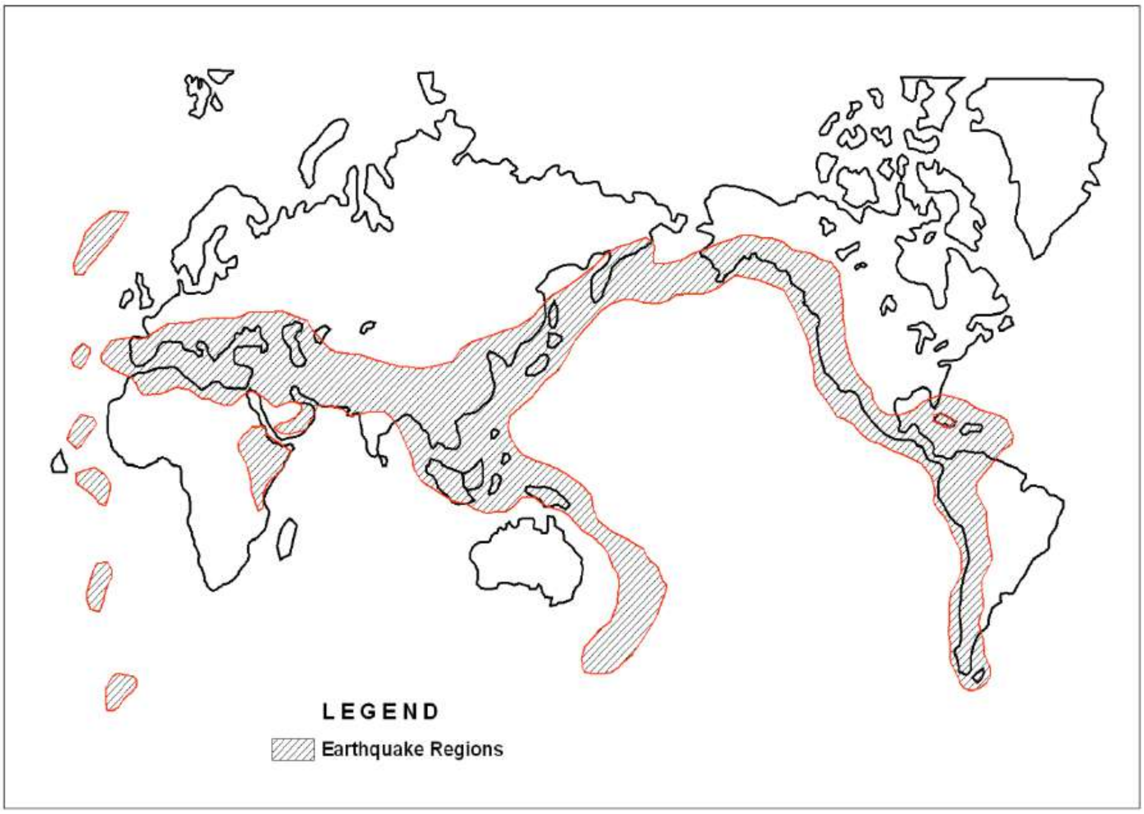
a. The Circum-Pacific belt.
b. Mediterranean-Himalayan Seismic belt.
c. Mid-Oceanic ridges and East African rift valley system.

8.9.a. The Circum-Pacific Belt: Nearly 80% of all terrestrial earthquakes is concentrated in this belt. This region coincides with the Circum Pacific Ring of Fire. It has oceanic trenches, and associated island areas where plates converge and the oceanic lithosphere submerges in the Asthenosphere. Alaska, Japan, and Philippine trenches are found here. It also extends towards the Indonesian trench and Newzeland. Most of the earthquakes occur in plate boundaries. These are caused by Stress at the Plate margins. This type of earthquake is common in Japan.

8.9.b. The Mediterranean-Himalayan Seismic belt: It runs from Gibraltar to the East through the Atlas Mountain, Pyrenees, Alps, Balkan Mountains, mountain chains of Asia Minor, Caucasus, Hindukush, and Himalayan Mountain chains up to Myanmar and the islands of Indonesia. This region does not consist of any oceanic trenches but continental plates.

8.9.c. Mid-Oceanic ridges and East African Rift Valley: Shallow focus earthquakes are found in these belts. This region is located on major fracture zones where the plates diverge, and the rising magma forms the new oceanic crust. It extends along the Red Sea and the rift valley of Africa.

Figure: 8.1
Earthquake regions in the world



8.10: LET US SUM UP

In this unit you have studied about the sudden force operating under the surface of the earth. Earthquakes are caused by several forces. They are modifying the existing landforms over the surface. It has several advantages and disadvantages. This force is found in different parts of the earth.

8.11: KEY WORDS

Endogenetic force, Focus, Epicentre, Seismology, Seismic Wave, Homoseismals, Isoseismals Line, Rossi-Forrel's Scale, Mercalli Scale, Tsunami.

8.12: QUESTIONS FOR SELF-STUDY

1. Explain the causes and effects of an earthquake.
2. Describe the major earthquake zones in the world.
3. Why are earthquakes common in young fold mountain regions?
4. Write a short note on –
    a. Seismic focus
    b. Earthquake waves
    c. Richter Scale
    d. Mercalli Scale.
    e. Tsunami

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