

BLOCK - II

OROGENY

Orogeny means mountain building activities. In this block the features and activities that are occurring on the surface due to the dynamic activities within the earth as earthquakes, volcanoes and mountains are explained.

The units included in the block are :

Unit 4 : Mountains

Unit 5 : Earthquakes

Unit 6 : Volcanoes

UNIT-4 MOUNTAINS

Contents

- 4.0 Objectives
- 4.1 Introduction
- 4.2 Classification of Mountains
- 4.3 Mountain Building Activity
- 4.4 Mountain Ranges in India
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4.0 OBJECTIVES

After studying this unit, you should be able to:

- define the mountain
- describe the types of mountains
- define the terminology of mountains
- describe mountain building activity

4.1 INTRODUCTION

A mountain is a conspicuous highland with small summit area. In the study of mountains, we come across certain terms such as **cordillera**, **system**, **range**, **group**, **chain** etc. A high land composed of a large number of mountains without definite arrangement, is known as mountain **group**. A mountain range consists of mountains arranged in a long narrow belt. Such mountains are closely associated in age and origin. A mountain system consists of many ranges and groups, all of which are related in age and mode of origin. Where mountain systems independent in age and origin, occur in more or less parallel rows they may be called mountain **chain**. A **cordillera** is a combination of chains, systems and ranges in one general portion of a continent.

Mountains differ in their mode of origin and life histories. One may be eruptive or volcanic resulting from the extrusion of lavas and their accumulations or they may be the result of intrusion of an igneous body into other formations that being eroded away from the igneous mass after it has cooled and hardened, leaving it standing out as a hill or mountain. Still other may be the result of direct uplift above the surrounding region.

Mountains are formed also as the result of folding or tilting of blocks produced by faults. But the great mountains belts girdling the earth owe their origin primarily to massive disturbances of bed rocks. The term mountain building very commonly used in geology is applied to creation of large, elongate high lands by large-scale deformation or folding, faulting and metamorphism. The term **Orogeny** has essentially the same meaning as mountain building. These effects of

mountain building are conspicuous also on the site of ancient mountain belts that have been now reduced to low altitudes by prolonged denudation through the ages. Mountains formed by the process of deformation of the crust are the most illustrative if somewhat puzzling features of the Earth's surface. Their formation by uplift to great heights has allowed cutting by rivers and streams to unusual depths. As a result such folded mountain regions have the finest display of bed rock including great thickness of sedimentary strata containing several marine fossils. Mountains therefore seem to stand on the site of ancient seas.

In exceptional cases, single isolated mountains may be found. Usually they are the result of extensive erosion of a region or of volcanic activity. There are quite a good number of mountain chains in the world. No two mountains are alike. Every mountain range presents a challenge to a person who wants to study the history of its formation.

Studies of historical geology show clearly that mountains have been formed during every era and probably in every period of earth's history. The spectacular heights of many of the deformation mountain chains have been attained slowly and gradually in several stages. The mountain building activity is known as **orogeny**. The areas where these activities take place are known as **orogenic belts**. Orogenic movements are essentially tangential to the crust. Great mountain building activity starts in the region where there was earlier a geo-syncline. Geo-syncline provides site for the deposition of material. The deposited material slowly gets uplifted due to tangential movements. In India the lofty Himalayas are the products of uplift of sediments deposited in the then existing Tethy's sea.

Check Your Progress

Note: a) Space is given below for writing your answer.

b) Compare your answer with the one given at the end of this unit.

1. What is orogeny?

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4.2 CLASSIFICATION OF MOUNTAINS

Mountains are classified on the basis of their origin broadly into five types. They are (i) Relict type (ii) Tectonic type or Deformation type and (iii) Accumulation type (iv) Dome mountains and (v) mountains of the sea.

The agencies involved in mountain making process are volcanic activity, differential erosion and crustal movements.

i) Relict type of Mountains (Residual Mountains): Relict type of mountains is formed due to differential erosion. Relict types of mountains are also known as **circum denuded type** of mountains. Most of the mountains in Peninsular India like 'Eastern Ghats' and 'Western Ghats' are classified as Relict type of mountains. Relict type of mountains are formed when an area undergo different degrees of erosion. Surrounding part gets more eroded leaving the central portion to escape the erosion.

ii) Deformation type of Mountains or Tectonic type of mountains: These can be divided again into fault type and fold type of mountains.

Fault types of mountains or produced due to the displacement or dislocation of rock blocks on either side along a plane of weakness. Fault types of mountains are also known as Block

Mountains which result due to displacement of blocks of rocks either from a ridge or a low land. The raised part of ridge is called **Horst**, depressed area is called **Graben**. Majority of the Himalayan range owe their present structure to the thrust faulting on a gigantic scale due to the shortening of Earth's crust.

Fold type of mountains: Another very important tectonic type of mountain is the fold type. In this type several stages are noticed. They are (a) Accumulation of Sediments in subsiding geo-syncline. (b) These sediments are subjected to lateral pressure due to tangential movements. (c) Upliftment of these sediments to form folded mountains. Majority of world mountain systems are a series of strongly folded type.

iii) Accumulation type of mountains: When volcanic eruption takes place, solid and liquid lava is given out. The volcanic products heap up to form volcanic mountains or what are known as **accumulation mountains**. These are also called as **volcanic mountains**. Most volcanic mountains consist of successive layers of ash, dust and coarser pyroclastic fragments interbedded with sheets of lava. Those which eject great quantities of solid rock fragments as a rule have higher and steeper peaks than the volcanoes which emit highly fluid lavas.

iv) Dome Mountains: - In a number of mountainous regions where the mountains occur as irregular groups, the central area is composed of intrusive rocks such as granites around which sedimentary rocks are found dipping in all directions away from the igneous core. The structure of the strata indicates that they once formed a continuous roof over the igneous mass. Such structures are formed where magma is injected into the earth's crust in such a liberal quantity that the surface strata are arched upward into a domelike structure called **Laccoliths**. Erosion subsequently removes the strata from the top of the dome and irregular hills and mountains are carved from the underline igneous core of granitic rocks.

v) Mountains on the Sea Floor: - Conspicuous mountain ranges are known to exist on the floor of the sea. The greatest of these is the **Mid-Atlantic Ridge** which winds down the Middle Atlantic from Iceland almost to Antarctica. It is thought to be the mightiest single mountain system on earth. It is atleast 10,000 miles long and 500 miles wide, more than twice the width of the Andes and with many peaks loftier than most continental mountains. Its summits lie one mile or more below the surface of the sea throughout most of its length, but some of the highest peaks are the scattered islands of the Atlantic such as the Ascension Island, the Azores etc. The highest of all called **Mount Pico** of the Azores, towers, 7,613 feet above the surface of the sea and plunges 20,000 feet below the surface.

The Island areas of the western Pacific Ocean represent zones of sharp mountain folds with great ocean deeps along the outer sides of the areas. These zones include a series of widely spaced geanticlines such as the Marians Two-Jima west Caroline and Palau- Kyushu and Nanseishoto. The island festoons represent high points many of which are active volcanoes along the crests of geanticlines arches.

Check Your Progress

Note: a) Space is given below for writing your answer.

b) Compare your answer with the one given at the end of this unit.

2. Name any two examples for relict type of mountains.

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4.3 MOUNTAIN-BUILDING ACTIVITY OR OROGENY

It is now a common understanding that the rocks of the great mountain systems of the world both past and present originated as sediments laid down in certain mobile zones called geosynclines. In general these geosynclines have been long and relatively narrow depressions which seem to have subsided during the accumulation of sediments in them. In these long narrow water tracts sedimentation would proceed on more or less definite lines.

There are three types of geosynclines

(i) Monogeosynclines: - These are the geosynclines as conceived by **Hall** and **Dana**. This type is perhaps best seen in the Appalachian Mountains of North America. They were long and narrow water basins which underwent considerable subsidence but there appears to have been a nice balance between sedimentation and subsidence because the materials are usually such characterized shallow water deposits. They were situated either within a continent or just on its borders.

(ii) Polygeosynclines: - These were rather wide water areas certainly broader than monogeosynclines. They have had very complex histories and have been diversified by the production of one or more parallel geoanticlines arising from their floors in the squeezing out processes. Rocky mountain geosynclines are a typical example of this type.

(iii) Mesogeosynclines: - In contradistinction with the above two types these are really narrow, elongated and mobile ocean basins which are actually bordered by continents. They are in fact, true Mediterranean's. They have waters reaching abyssal depths and have had long and intricate histories. They may be interrupted by the development of geanticlines.

The Mesogeosynclines always situated between continental masses. In fact they were the mobile zones between the surrounding rigid masses. In a general way the history of a geosynclines may be divided into three distinct phases (a) its evolution due to sinking and sedimentation (b) its revolution during which anticlinal ridges may rise giving place to the formation of great overthrust masses and finally (c) the collapse of the geosynclines

Great mountain-building movements have been particularly active during certain periods of the Earth's history. When vast sediments of the geosynclines were intensely compressed due to Earth-movements the resulting folded belts are described as Orogenic (Gk. Oros- a mountain). Mountain building also called as Orogenesis and the time of mountain-building is called an orogenic revolution. At least a dozen major revolutions besides minor disturbances have now been recognized in various parts of world.

So an orogenic belt is an elongated structural zone of the earth's crust in which the rocks have been folded, crumpled, contorted or over thrust on a spectacular scale. As a consequence of the thickening of the crust due to such an intense lateral compression long sections of each orogenic belt are uplifted thereby becoming mountain ranges like the Alps and Himalayas. Most of the great mountain ranges of today are parts of Orogenic belts that came into existence at various periods of crustal unrest particularly during the Tertiary era.

In every case mountain building follows a general trend of events. Processes connected with mantle produce **geosynclines and geoanticlines**. Erosion of geoanticlines produces sediments for geosynclines resulting in the subsidence of geosyncline and rise of geoanticlines. Metamorphism and granitic intrusion takes place with subsidence. Geosynclinal folding takes place giving rise to mountain building activity involving thrusting of older masses over younger strata. The origin of orogeny may be explained according to the theories of '**convection currents**', '**plate tectonics**' etc.

Formation of complex fold mountains due to deformation of crustal movement is generally associated with intrusion of magma. The magmatic intrusion may be due to the increase of pressure and upliftment of sediments. Granite batholiths are generally associated with complex folded mountains as magmatic intrusions.

Check Your Progress

Note: a) Space is given below for writing your answer.

b) Compare your answer with the one given at the end of this unit.

3. Explain about geosyncline.

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4.4 MOUNTAIN RANGES OF INDIA

India is broadly divided into three physiographic divisions namely Peninsular India, Extra peninsular India and Indo-Gangetic alluvial plain.

The mountains belonging to the peninsular India are different from the mountain of extra Peninsular India. In peninsular India we have the oldest mountain ranges known as Aravali Mountains. This mountains range divides Rajasthan into two parts. The present length and height of this range is only poor remnant of mighty Aravali mountain chain. Satpura and Vindhyan mountains are in Central India. Eastern Ghats and Western Ghats are on the east and west coast of peninsular India. All these mountains are of relict type. In the extra peninsular India we have the highest mountain chains of thee world known as **Himalayas**. Himalayas extend from Indus bend in the northwest to Brahmaputra bend in north east. The Himalayan mountain chain fall under the category of deformation type or tectonic type because they exhibit faulted and folded structures.

Check Your Progress

Note: a) Space is given below for writing your answer.

b) Compare your answer with the one given at the end of this unit.

4. Name the three parts of mountain ranges in India.

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4.5 SUMMARY

The internal geologic processes are acting within the earth. These processes are mainly diastrophism and igneous activity. These activities are causing volcanic eruptions, mountain building processes and earthquakes. A mountain is a conspicuous high land mass elevated appreciably above the average altitude. On the basis of their mode of origin, mountains are grouped as Relict type of mountains, Tectonic Mountains and Accumulation Mountains. Relict 35

types of mountains are formed due to differential erosion. Tectonic mountains are also called as Deformation Mountains with subgroups as fold mountain and fault mountains. Accumulation Mountains are formed due to the accumulation of sediments and with upliftment and subsidence. Volcanic mountains are formed due to the accumulation of volcanic products.

In India we are having Aravali, Satpura, and Vindhyan mountains. We have mighty Himalayas in the North, Easternghats and Westernghats in the South. Mountain building activity follows processes connected with mantle which produce geosynclines and geoanticlines. Complex Fold Mountains are formed due to deformation of crustal movements.

4.6 CHECK YOUR PROGRESS-MODEL ANSWERS

1. The mountain building activity is called as orogeny.
2. Easternghats and Westernghats.
3. The mountains are classified on the basis of their origin. The different types of mountains are (i) Relict type (ii) Tectonic type or Deformation type (iii) Accumulation type.
4. The three physiographic parts of India are (i) Peninsular India (ii) Extra Peninsular India and (iii) Indo-gangetic alluvial plain.

4.7 MODEL EXAMINATION QUESTIONS

I Answer the following questions in 30 lines.

1. Describe in detail about mountains
2. Explain the classification of Mountains
3. Describe the Mountain building activity
4. What are geosynclines? Write about the types

II Answer the following questions in 10 lines.

1. Write down the mountain ranges of India
2. Describe how Fold Mountains are formed
3. Describe the Mountains of the sea Floor

UNIT-5 EARTHQUAKES

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- 5.0 Objectives
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- 5.2 Recording of Earthquakes
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- 5.6 Causes of Earthquakes
- 5.7 Distribution of Earthquakes
- 5.8 Summary
- 5.9 Check Your Progress- Model Answer
- 5.10 Model Examination Questions

5.0 OBJECTIVES

After studying this unit, you should be able to

- define earthquakes
- classify earthquakes
- describe the cause of earthquakes
- explain the distribution of earthquakes

5.1 INTRODUCTION

Numerous physical forces are continuously at work within the body of the earth and up to its surface. The agents working on the surface are constantly changing the shape and size of the features that give its variety and beauty. Likewise, the physical forces beneath the surface are rearranging rock materials by shifting magmas and crustal movements. Some movements are slow and radial where as some others are sudden and tangential.

The sudden and tangential movements inside the earth surface produce tremors in the rocks. Such sudden movements beneath the earth's surface are known as **earthquakes**. No other demonstration of the mighty forces at work within the earth is as terrifying to man as are earthquakes. They occur suddenly and swiftly, cover vast areas and leave everything in shambles. Mountain making is an evidence of tremendous forces that act upon the surface of the earth, but the growth of mountains is so slow that man's life span is too short to enable him detect the movements that takes place. It is very different with earthquakes. The solid land shakes, surface objects are destroyed in few seconds. Earthquakes come without warning. In spite of great advancement, science has failed to safeguard man against earthquakes in devising methods of detecting them in advance. **Herodotus, Plain** and many other Philosophers and historians

mentioned earthquake occurrences and destructiveness. The earliest recording of earthquakes dates back as early as 2500 years ago.

Check Your Progress

Note: a) Space is given below for writing your answer.

b) Compare your answer with the given at the end of this unit.

1. What are Earthquakes?

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5.2 RECORDING OF EARTHQUAKES

The first instrument made was able to record only the fact that there had been an earthquake and did not furnish information regarding its magnitude or velocity. This instrument called **siesmoscope** which was invented in 136 A.D. by Chinese.

In principle a **seismograph** consists of a heavy mass suspended like a horizontal pendulum, pivoted against a massive support which is firmly attached to the ground so that it shakes with the vibration of the ground. Because of its inertia the weight tends to remain stationary. It is the relative movement between the weight and the rest of the instrument that is recorded, after being suitably magnified. A small mirror attached to the weight reflects a beam of light on to a sheet of photographic paper wrapped around a cylindrical drum which rotates on a long screw. While rotating, the drum carries the paper along at right angles to the beam of light. The vibration is thus recorded continuously.

A seismograph record is called **Seismogram**. The exact time of the beginning and ending of the shock and the intensity of the shock can be deduced from this record.

The science of determining the size and character of earthquakes is called **Seismology**. The detailed record of an earthquake is made on an instrument called **seismograph** which was invented and first used in Italy in 1841. The record of an earthquake shock is called **seismogram**.

Check Your Progress

Note: a) Space is given below for writing your answer.

b) Compare your answer with the one given at the end of this unit.

2. The science which deals with earth quake is

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5.3 EARTHQUAKE WAVES

When earthquakes occur there is a release of energy in the form of plastic waves, these waves generated during sudden crustal disturbances beneath the earth surface are called seismic waves. These are of four types. They are (i) Longitudinal waves (ii) Shear waves (iii) Ray Leigh waves (iv) Love waves.

Longitudinal waves consist of alternating pulses of compression and refraction acting along the direction in which the waves travel. They are like sound waves. Longitudinal waves are commonly known as “P” waves.

Shear waves create oscillations at right angles to the direction of wave travel. They are similar to light waves. Shear waves are also known as “S” waves.

By Ray Leigh waves the particles are set in to motion in circles lying in vertical planes. Love waves make particles oscillate along the line in horizontal plane at right angles to the direction of wave travel. These two types of waves are together known as surface waves or L-waves.

‘P’ waves travel with greater velocity than the ‘S’ waves. ‘P’ waves and ‘S’ waves are together known as body waves where as ‘L’ waves are called surface waves. Among ‘P’, ‘S’, ‘L’ waves, ‘P’ waves are the fastest and then come the ‘S’ waves and the ‘L’ waves last of all.

‘P’ waves can travel through solids and liquids where as ‘S’ waves can travel only through solids but are obstructed by liquids.

Check Your Progress

Note: a) Space is given below for writing your answer.

b) Compare your answer with the one given at the end of this unit.

3. Write about the earthquake waves

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5.4 INTENSITY OF EARTHQUAKES

To know the strength and severity of the earthquakes, we need a scale of reference to measure its intensity. The intensity is measured by the effect of an earthquake on a seismograph or by the sensation of people, and by the damage it has caused to the life and property. The first seismograph to be introduced is that by Italian **seismologists Rossi and Forrel** and therefore the intensity scale is known as **Rossi Forrel Scale**. Rossi Forrel, Scale consists of ten (10) divisions. The higher the number in the intensity scale, greater will be the effect of the earthquake.

Mercalli, another Italian Seismologist, put forth another scale with 12 divisions. In this scale the measure of the intensity depends upon the acceleration produced by the seismic waves.

The latest scale used to measure the intensity of the earthquake was given by **Richter** and it is known as **Ritcher scale**. All the recent earthquakes recorded have been measured on **Richter scale**. It is the one that is normally followed now.

A line drawn through all places having the same intensity of earthquakes is known as **isoseismal line**. By comparing the intensities at the epicenters along the isoseismal line we can calculate the depth of the focus of an earthquake.

5.5 CLASSIFICATION OF EARTHQUAKES

The Earthquakes are classified on the basis of the depth of the focus. Focus of the earthquake means the exact place of disturbance beneath the earth’s surface. Focus is also called as hypocentre. The vertical projection of focus point on to the surface of the earth is called

epicenter. No earthquake has been recorded whose focus is deeper than 700kms. All earthquakes which originate at a depth of more than 300kms. Or whose focus is deeper than 300Kms are called **deep focus earthquakes**. If the focus is in between 70 to 300 kms such earthquakes are called **Intermediate focus** earthquakes. Such earthquakes have been recorded in south western Asia and Mediterranean lands. Earthquakes with focus at a depth of less than 70 Kms are known as **shallow focus** earthquakes. Majority of the earthquakes fall under this category.

Some of the famous earthquakes of India and adjacent areas are Assam earthquake of 1897, Assam earthquake of 1950, North Bihar earthquake of 1934, Koyana earthquake of 1967 and Quetta earthquake of 1935. Latur earthquake of 1993, Bhoj earthquake of 2001, 2005 Uttarakhand, 2009 Andaman Islands, 2015 Nepal and 2015 Afganistan.

The study of these earthquakes shows that in the Himalaya region, where younger rocks come into contact with older rocks, earthquakes are frequent. These areas are very unstable and dislocations are often caused to relieve the strain.

Check your Progress

Note: a) Space is given below for writing your answer.

b) Compare your answer with the one given at the end of this unit.

4. Point out the basis for the classifications of the earthquakes?

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5.6 CAUSES OF EARTHQUAKES

Earthquakes originate due to various causes. These are in the order of importance faulting, volcanism, landslides and collapse of cavern roof etc. Landslides and collapse of cavern roofs may not be the cause of the earthquakes but they may be the effects of the earthquakes. Vast majority of earthquakes originate within 16 kilometers of the surface, and may be due to cause acting at much greater depths. Earthquakes are directly associated with earth movements along faults. It is this movements associated with faulting which sets up elastic waves that produce an earthquake.

The movement along faults is influenced by many factors, the main one being the amount of strain that has accumulated in the rocks. It also depends upon the character of the fault whether it is old one or a new one.

Prof. H.F Reid, after careful study of the 1906 San Francisco earthquake along **San Andreas** fault has proposed a new idea for the origin of earthquakes which is known as **Elastic rebound theory**. According to this theory the sudden shifting of rock along a fault, which is the normal causes of earthquakes, is the result of quick relief of elastic stress which accumulates by slow shifting of adjacent portion of the earth's crust in opposite direction until the rocks can no longer withstand the strain.

Therefore, it is believed that most of the earthquakes are due to structural disturbances which are termed as tectonic earthquakes. Tectonic earthquakes are the results of tectonic movements.

40 Earthquakes are also caused by volcanoes. The movements of magmas and gases within the

earth's crust may result in earth tremors. It has long been known that earthquakes accompany the volcanic eruptions. Earthquake shocks may occur before an eruption, which is a warning for volcanic activity, but greater number of shocks follows the volcanic eruption indicating the readjustment taking place between the magmas and the surrounding rocks below the surface. Earthquake shocks which accompany volcanic eruption are less severe and less destructive than those caused due to the faulting.

Submarine Earthquakes: Earthquakes which occur under the sea water are called submarine earthquakes. They cannot spread very far in sea water. They can be recorded by seismograph and felt by passing ships. The effects of submarine earthquakes on sea waves are and produce vertical dislocation on the sea bottom and cause huge sea waves which are known as **tsunamis**.

Check Your Progress

Note: a) Space is given below for writing your answer.

b) Compare your answer with the one given at the end of this unit.

5. Who proposed the elastic-rebound theory

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5.7 DISTRIBUTION OF EARTHQUAKES

The destructive earthquakes are concentrated in a ring surrounding the Pacific Ocean . This ring coincides with the circum pacific ring of fire.

The second chain is termed as East-Indian, which extent over Indonesian, Andaman- Nicobar, Islands and Burma.

The third belt extends from the Pamir Knot to Afghanistan, Iran, Turkey, Greece, Rumania, Altai Mountains, Gibralatar and the Azores Islands.

A belt also extends from the Gulf of Aden, between Seychelles and Maldives Islands, turns to the West-South of Africa and goes up to the Falkland Islands.

Another belt also runs along the Great Rift Valley of East Africa.

5.8 SUMMARY

The sudden and tangential movements inside the earth surface produce tremors in the rocks. Such sudden movements beneath the earth surface are known as earthquakes. Earthquakes with high intensity are causing large scale destruction of life and property. For recording the earthquakes first an instruments called seismoscope was invented by Chinese in 136 A.D. Now a day's seismograph instrument is used to record the seismic shocks, and the records of seismic shocks prepared and presented by seismograph are called seismograms. The science of studying the character of earthquakes is called seismology.

When Earthquakes occurs, lot of energy is released in the form of seismic waves. These seismic waves are classified into four types, namely Longitudinal waves, Shear waves, Rayleigh waves and Love waves. Longitudinal waves are also called 'P' waves and can travel through solids and liquids. Shear waves or 'S' waves can travel only through solids. Various scales have been proposed to estimate the intensity of earthquakes from the amount of damage caused. The main types are Rossi- Forrel Scale, Mercalli Scale and Richter scale. Among these the Richter scale is the most popular one.

The earthquakes are classified on the basis of the depth of the focus. Focus means the exact place beneath the earth surface where disturbance starts. All earthquakes whose focus is more than 300kms are called deep focus earthquakes. If the depth of the focus is in between 70 and 300kms. then they are called intermediate focus earthquakes. Earthquakes with focus at a depth of less than 70kms are known as shallow focus earthquakes. Earth quakes are caused due to the earth movements along faults. H.F. Reid proposed elastic rebound theory for earthquakes. It states that the sudden shifting of rock along a fault results in release of elastic stress. Therefore most of the earthquakes are due to structural disturbances. Earthquakes are also caused by volcanoes. The submarine earthquakes on sea bottom causes huge sea waves called Tsunamis.

Earthquakes are distributed along two major belts namely Circum-Pacific ring of fire and second chain extends over Indonesia, Andaman- Nicobar Islands and Burma. Now a day's earthquakes are occurring everywhere due to human activities.

5.9 CHECK YOUR PROGRESS-MODEL ANSWERS

1. The sudden and tangential movements within the earth surface are known as earthquakes.
2. The science of earthquakes is called Seismology.
3. There are four types of earthquake wave's namely Longitudinal waves, Shear waves, Ray-Leigh waves and Love waves.
4. Based on the depth of the focus earthquakes are divided into deep focus, intermediate focus, and shallow focus earthquakes.
5. H.F. Reid proposed elastic rebound theory.

5.10 MODEL EXAMINATION QUESTIONS

I Answer the following questions in 30 lines each

1. What are the causes and effects of earthquakes?
2. Give a brief account of classification of earthquakes.
3. What are the methods used for detecting and recording of earthquakes?

II Answer the following questions 10 line each

1. Write notes on epicenter and focus.
2. Write notes on earthquakes belts.

UNIT - 6 VOLCANOES

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- 6.2 Volcanic Products
- 6.3 Volcanic Eruptions and Cones
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- 6.5 Volcanic Activity
- 6.6 Causes of Volcanism
- 6.7 Distribution of Volcanoes
- 6.8 Summary
- 6.9 Check Your Progress-Model Answers
- 6.10 Model Examination Questions

6.0 OBJECTIVES

After studying this unit, you should be able to:

- define the term volcano
- explain the various volcanic products and types volcanoes
- describe the causes of volcanism
- explain the distribution of volcanoes

6.1 INTRODUCTION

The term Volcano is derived from the name **Vulcan**, the Roman God, applied to Mt.Etna in **Sicily** and to some of the volcanoes of the **Lipari Islands** north of **Sicily**. The term **Vulcanism** is used to embrace all aspects of volcanic activity. The name **volcano** is generally applied to the surface from which develops around a central vent which may be an orifice or a fissure through which hot incandescent magmatic materials are continuously or intermittently ejected. It is often symmetrical in shape. A volcanic mountain differs structurally and genetically from the majority of the world's mountains. As the solid materials accumulate around the vent of conduit they build up a cone which increases in size until a huge volcanic mountain is formed. A cone so constructed is called a volcano.

Volcanoes may vary in size from small conical hills to some of the loftiest mountains on the earth's surface. Some of the highest peaks like **Cotopaxi** in **Equador** have the distinction of being the highest volcano 6380 mtrs **Mount Kilimanjaro**, **Mount Fiji** and **Mount Mayon** are examples of such perfect conical shape. The **Hawaiian Islands** are volcanoes that reach a

height of more than 4200 mtrs above sea-level and they are built on the ocean floor of the **Pacific** where the depth is more than 4200 to 5400 mtrs. Not all Volcanoes are active at present and some of them have become extinct like the **Mt.Shasta**, **Mt.Rainier**, **Mt.Hood**, **Mt.Baker** in the cascade ranges of western U.S. **Mt.Etna** in Sicily is a high mountain built as a volcano that is still active. Every well-developed volcanic cone has near its top **volcano crater**, a kind of funnel-shaped depression out of which volcanic material are thrown out, up during explosive eruptions. In some volcanoes lavas emerge through the crater, in others they break through the sides of the cone or emerge from the fissures beyond the base. It should be noted that the magma is not merely molten rock but it differs essentially from the latter in being charged with gases and volcanic constituents. While the magma is confined under high pressure, its gaseous constituents remain dissolved, but as it comes on to the surface the overhead pressure is reduced and the gases begin to get liberated either freely or explosively according to local circumstances. The molten matter erupted at the surface is thus relatively impoverished in gases and volatiles and then is called **lava** to distinguish it from the original **magma**. In a volcanic eruption not only the eruption of hot gases and molten lavas, but also vast quantities of fragmental materials often produced by the explosion of rapidly liberated gases. Such materials are collectively known as **pyroclastics** and they contain from the finest particles to masses of **scoria** and **volcanic bombs** of considerable size. The popular belief that volcanoes are burning mountains because the volcanic pyroclastic materials including hot gas often may be luminous because they are incandescent.

Check Your Progress

Note a) Space is given below for writing your answer.

b) Compare your answer with the one given at the end of this unit.

1. Describe Volcanoes.

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6.2 VOLCANIC PRODUCTS

The products of volcanic eruption consist of gases, rock fragments of different sizes and finally the lavas of different composition. Steam is the commonest of the volcanic gases. It is discharged by active volcanoes in immense quantity as indicated by the great height and enormous volume of the clouds that accompany many eruptions. These clouds consist of the dust and ash by the up-rushing column of steam and other gases. Due to friction between ash particles and with atmospheric disturbance, the volcanic eruptions and the rains by electrical manifestations culminate in spectacular lightning discharges. Other gases of volcanic origin in order of abundance are CO₂ and smaller proportions of H, C, O, S and Cl.

The pyroclastic materials that are blown into the air by the explosive activity of volcanoes and shower down at various distances from the cone, vary very much in size from fine volcanic dust and ash to big volcanic bombs. These materials are classified in the following manner
 1) Pieces larger than 32mm in diameter are called **blocks** if ejected as solid and angular fragments. 2) **Bombs** if ejected as clots of molten lava and hence somewhat roundish or ellipsoidal. 3) **Lapilli** or **cinders** which are between 32mm and 4mm. 4) **ash** which are between 4 mm and 1/4mm and still finer material is called **volcanic dust**.

The volcanic ejectments in part are composed of solid rock and in part of a spongy, cellular or vesicular character. This vesicular condition is due to the fact that while most of the gas is escaping into the air and carrying fragments with it, a minor part is expanding within the particles of the liquid lava puffing them up into cellular forms.

The bombs, lapilli or cinders and most of the ash fall near the volcanic vent and thus help build an edifice round it called the **volcanic cone**. The dust is carried for long distances and spread over an immensely large area. Microscopic volcanic dust from the great catastrophic eruption of the **Krakatao volcano** in 1883 encircled the whole world and its dispersion through the atmosphere was reasonable for the vividly colored and quite spectacular sunsets that were seen during the following months. The projectile power of the volcanoes is simply astounding. Thirty-ton blocks of rocks were blown out by the **Stromboli** in 1930 to a distance of about 3 kms. Even more astonishing are the huge blocks up to several hundred tons carried forward for miles by the **pelean** clouds of **Mont Pele** during the great eruption in 1929.

Lavas: In volcanoes the liquid rock materials that comes out of the vent is called **lava**. As the magma releases out lava it cools on the surface, darkens and crusts over. It is very viscous and its under part may still be moving while the upper part crusts over and breaks up into rough angular jagged blocks which are borne as a tumbling lava flow. Its surface consist of a chaotic blocks with sharp points. Such lavas are called **block lavas**. In Hawaiian Islands it is called **aa**. They are difficult to cross on foot.

In marked contrast to the block lava other lava flows harden with smooth surfaces which have curious ropy or curved or corroded forms. They are called **Ropy lavas** in Hawaiian Island. Ropy lavas begin to crystallize at a higher temperature, minute bubbles of gas escape quietly and the flow congeals with a smooth skin which wrinkles into ropy and corroded forms like those assumed by flowing pitch or coal tar.

When a lava of the ropy type flows over the sea floor or otherwise beneath the chilling cover of water, it consolidates with a structure like that of a jumbled heap of pillows appropriately called **pillow lava**. By the time each emerging tongue of lava has swollen to the size of a pillow the rapidly congealed skin prevents its further growth. This type of pillow lava is common in the submarine lavas associated with geosynclinal sediments of former geological periods.

The mobility of molten lava depends upon its composition. Silica rich lavas are usually stiff and viscous and congeal as thick tongue before they have traveled far. The appearance and character of a lava stream depend upon several factors. The chemical composition of the magma determines the nature of the resulting rock whether it is light colored lava (**rhyolite**) or **black basalt** or of intermediate character as **andesite**.

Check Your Progress

Note a) Space is given below for writing your answer.

b) Compare your answer with the one given at the end of this unit.

2. Classify the pyroclastic materials.

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6.3 VOLCANIC ERUPTION AND CONES

The eruption of a volcano is often preceded by earthquake and by loud rumblings like thunder which may continue on gigantic scale during the course of eruption. The loud rumblings are probably due to the movement of gases and molten rock that are held in under great pressures. During one of the greatest volcanic eruptions like that of **Tambora** on **Sumbawa Island of Indonesia** in 1815, the land rumblings were heard over an area of 1,000 kms radius.

The nature of a volcanic eruption is largely determined by the type of materials ejected from the volcanic vent. These products are gases, molten rock or solid fragments. A given volcano may emit all the three types of products but in some regions a certain product predominates. Thus the Hawaiian volcanoes generally discharge very hot and highly fluidal lava from which the enclosed gases escape very rapidly. Such eruptions are non-explosive. On the other hand, some volcanoes erupt with great explosive violence. **Mt. Pele** on the island of **Martinique** in the **West Indies** is a typical example of explosive type. In May, 1902 it began to erupt in a series of violent explosions but discharged almost no lavas. Intermediate between these two extreme types is the one exemplified by **Stromboli** in the **Mediterranean Sea** which erupts mildly every 15 minutes hurling small masses of partially solidified lava into the air. Steam also released from the openings and forms a cloud, which reflects the light from the incandescent lava.

Volcanic eruptions are broadly categorized into two types (1) **central eruptions** and (2) **fissure eruptions**.

Majority of the present day volcanoes belong to the central type but during certain periods of geological time the fissure type eruptions have poured out lava and which covers the surroundings country as sheets of greater size than the limited flows of central types of eruptions.

Whenever eruptions takes place through a vertical chimney, the orifice is widened into a crater with flaring sides by outward explosion and inward lumping. But with the accumulation of volcanic products around the vent a conical or dome shaped mountain is gradually built up. Volcanoes with the familiar **cone** and **crater** structure are said to be of the central type, because the volcanic activity is centralised around a pipe-like conduit. The top of a volcano generally is marked by a pit or crater. The crater may be widened to great size due to repeated eruptions.

6.4 TYPES OF VOLCANOES

Successive eruptions from a single vent build the mountainous accumulation of material known as volcanoes. Three types of volcanoes are generally recognised. a) Shield volcano b) Cinder cones and c) Composite cones or Strato volcanoes. Each has a characteristic style of eruption and consequently characteristic form.

Shield Volcano: When highly fluidal lava is extruded, the volcano takes the shape of a broad slightly domed structure called a shield volcano. Shield volcanoes are built primarily of **basaltic** lava flows and contain only a small percentage of pyroclastic material. They have a slope of a few degrees at their flanks and not more than 10 degrees near summit. Typical example of a shield volcano is the **Mouna Loa** in the **Hawaiian Islands** which is one of the largest volcanoes in the world.

Cinder Cones: As the name suggests cinders are built up of ejected rock fragments. Because unconsolidated pyroclastic material has of a high angle of repose (between 30 and 40 degrees) these volcanoes have the steepest slopes. Cinder cones are built of chiefly of cinder and ash

and are generally circular in ground plan and have the form of truncated cone with a crater at its top. They are quite numerous in the Hawaiian Islands.

Composite Cones or Strato Volcanoes: These volcanoes consist of alternating layers of lava flows and pyroclastic materials. They have structures that are intermediate in form between the steep cinder cones and the flat domes of shield volcanoes. This composite construction shows that a volcano thus built was at times violently explosive in activity and at other times quite, swelling up streams of lava. The deposits of successive eruptions form layers, some of coarser and some of finer materials. Thus a crude layering or stratification is produced, the layers sloping down and out from the conduit of the volcano. The layering is further accumulated by the sheets of lava which are intercalated between the beds of fragmental ejects. **Mt Mayon** in the **Philippines** is the most active volcano of this type. Other examples include that **sacred** mountain of **Japan**, the magnificent **Fujiyama** towering 2700 meters above the surrounding country.

Calderas: Some volcanoes have usually large craters, with huge circular pit resulting from an explosive eruption or collapse of a former volcanic cone, they are called **calderas**. A name given after **La Caldera** of the **Canary Islands**. Most calderas are of great size and many of them are very wide as compared with their depth. Two splendid examples of depressions of this type are the calderas at the summits of **Kilonea** and **Mauna Loa** in **Hawaii**. Both these are formed by the collapses into the partially emptied magma chamber below. Such collapse is the result of the withdrawal of the lava column from below the shield-shaped cone either by eruptions on to the surface or by movements of magma within the crust. The impression is ample proof of the downward movement of the summits of the cones. Further the steep inner walls of many calderas are marked by concentric and interweaving fissures marking the slips and faults caused by the down-dragging cone. Here the magma is injected into the concentric fissures and dykes are formed.

Fissure Eruptions: Even though volcanic eruptions from a central vent are the most familiar, by far the largest amounts of volcanic materials are extruded from cracks in the earth's crust called, **fissures**. Rather than building cone, those long narrow cracks distribute volcanic materials over a wide area. An extensive area in western India was formed in this manner, and the numerous fissures extruded very fluidal basaltic lava. It is popularly called **Deccan Traps**. Another famous example of such fissure eruption is the **Columbia River plateau** in the North Western U.S.A. Because of the high fluidity of the basaltic lava large areas were indurated by such lava flows and the terms flood basalts appropriately describes the water like nature of these basaltic lava flows.

Check Your Progress

Note: a) Space given below for writing your answer.

b) Compare your answer with the one given at the end of this unit.

3. Explain Strato Volcanoes.

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6.5 VOLCANIC ACTIVITY

The nature of a volcanic eruption is determined largely by the type of materials ejected from the volcanic vent. According to the phases of the activity that is whether it is mostly explosive and effusive or mixed. A volcano emits different proportions of volcanic ejects.

Volcanologists have characterised the phase of activity of the volcanoes, as **1) Hawaiian, 2) Strombolian, 3) Vulcanian, 4) Vesuvian, 5) Plinian and 6) Pelean** as exemplified by the prevailing most characteristic habits of certain well known modern volcanoes. The explosiveness of magma depends upon its viscosity and gas content. If it contains no gas it has almost no explosive power. Viscosity is influenced by the chemical composition and it is diminished by increasing temperature and to some extent by the gas content. As the temperature and gas content of a magma change, the explosive nature of the magma also may change so that the same volcano, at different times, may go through different phases of explosive activity. Andesitic and rhyolitic lavas are more viscous than those of basalts and therefore are often associated with explosive types.

Hawaiian Type: This is the mildest phase of activity exemplified by many volcanoes in the Hawaiian Islands and hence the name Hawaiian type. They discharge very quiet flows of thinly liquid lava not accompanied by the explosive escape of gases. The lava emitted is very hot and highly fluidal and thin. Gas is given off but rather quietly jets and fountains of incandescent spray may be thrown up by the rapid emission of spurting gases. When caught by a strong wind the bulbs of molten lava are drawn out into long glassy threads known as **pele's hair** named after the Hawaiian **goddess of fire Pele**. Mouna Loa is the giant among the Hawaiian volcanoes with vast outpourings of basaltic lavas.

Strombolian Type: When less mobile lava is exposed to air in a crater the gases escape more sporadically with moderate explosive which may be rhythmic or almost continuous. Clots of lava often incandescent are blown out to form bombs or lumps of scoria, while in phases of more intense activity the explosions may give rise to luminous clouds. The volcano of **Stromboli** is in the **Mediterranean Sea** just north of Sicily in the Lipari Islands. It has been continuously active since the dawn of history, its eruptions being as a rule very much rhythmic consisting of mild explosions. A volcano is said to be in the Strombolian phase when it ejects clots of incandescent lava and the magma in its crater and does not crust over between consecutive explosions.

Vulcanian Type: This is the phase of activity exemplified by Volcano in **Lipari Islands**. Its lava is more viscous and pasty and quickly crusts over solidly between successive eruptions. Gases accumulate and gather sufficient strength beneath the congealed cover and below off at longer intervals shattering the crust formed after an earlier eruption, hurling angular fragments of rocks with great explosive violence. The resulting volcanic clouds are dark and dense and characteristically assume convoluted or "**Cauliflower**" shape as the gases and dust ascend high and expand. They are not incandescent even in nights. The major eruptions of several volcanoes begin with a vulcanian phase. Vulcanian is the term often used for eruptions in which only cold material is blown out. Activity of this type is mostly likely to occur during the cleaning out of a volcanic vent after the volcano has been dormant for quite some time.

Vesuvian Type: This is the paroxysmal extension of **Strombolian** and **Vulcanian** types, the new and characteristic feature being the extremely violent explosions of a magma which has become highly charged with gases during a long interval of mild activity. In consequence of the preliminary removal of the contents of volcanic pipe, down to a considerable depth, often as a result of escape of the lava through lateral fissures and vents, the overhead pressure on the underlying magma is relieved. The magma then bursts into explosive forth and expels itself as vast luminous and incandescent clouds of cauliflower form. These clouds ascend to very great heights and from them showers of ashes are widely distributed.

Plinian Type : The most violent Vesuvian type of eruptions sometimes culminate in a stupendous blast of up rushing gas which rises to a height of several miles and then spreads out into an expanding cloud of globular masses of gas and vapour. This phase was first observed in pliny during the catastrophic eruption of Vesuvius.

Pelean Type: The Pelean phase is the most violently explosive of all. Its eruption, clouds are denser than even those of Vulcanian. In this type the limit of high viscosity and explosiveness is reached. Upward escape is prevented by the growth of an abstractive dome above the conduit. Intermittent spurts of tightly compressed magma force their passage through the lateral cracks and each of these sweeps down the slopes as in intensively hot avalanche of self explosive fragments of lava lubricated by constantly expanding gases and vapours. These downward rolling explosive blasts, one of which nearly wiped out **St.Pierre in 1902**, are generally known as **Nue'es ardents**. But as a matter of fact, they do not glow as the French term suggests but are ink black in color and hence it is best to describe them as pelean clouds.

The extraordinary feature of a pelean clouds are that is ejected horizontally from beneath the lava plug in the summit of the volcano instead of blasting the plug out vertically upward. It is extremely hot and it travels at great speed carrying with it an enormous quantity of rock fragments including blocks many meters in diameter. This phase of activity derives its name from the volcano of **Mount Pele** situated on the Island of **Martinique** in the West Indies.

Submarine Volcanoes: Violent submarine volcanic eruptions have been observed in the volcanic belt of **Aleutian Islands** and in the south central Pacific ocean area. Cones may be built few hundred meters above sea level but when volcanic activity declined the small volcanic Islands are soon destroyed by the waves. **Pan teller** a small Island near **Sicily**, is such a submarine volcanic island.

Mud Volcanoes: Gases released out at the surface may carry with them particles of sand and clay which are deposited at the vent and as the process continues a small cone is built up. The sand and clay form mud with water which dries up and hardens the surface of the mount. Gases accumulate below the hardened surface until the pressure is sufficient to blow off the top of the cone in the miniature scale of a volcano. Therefore they are called mud volcanoes and are found mostly in areas where petroleum and natural gas bearing strata occur below, as is the case in the bank region of Russia. They are also found in the regions of volcanic origin in Burma.

Features Associated with decadent Volcanism: Many volcanoes give off steam and other gases during the dormant intervals between eruptions. Even after the volcanoes have ceased to be active, these emanations may continue to issue from the **crators** or their flanks. Also large bodies of magma that have ascended to the higher levels of the crust without reaching the surface on solidifying give off their dissolved gases which escape through fissures to the surface. These emanations issue at the surface either as gases when they are called **fumaroles** or as hot waters when they are called hot spring or **geysers**.

Check Your Progress

- Note: a) Space is given below for writing your answer.
b) Compare your answer with the one given at the end of this unit.

4. Classify the phases of Volcanic Activity

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6.6 CAUSES OF VOLCANISM

Volcanism is the phenomenon of eruption of molten rock (magma) onto the surface of the earth or a solid-surface planet or moon, where lava, pyroclastic and volcanic gases erupt through

a break in the surface called a vent. It includes all phenomena resulting from and causing magma within the crust or mantle of the body, to rise through the crust and form volcanic rocks on the surface.

The important causes for volcanism are

1. Movement of molten rock in the mantle, caused by thermal convection currents, coupled with gravitational effects of changes on the earth's surface (erosion, deposition, even asteroid impact and patterns of post-glacial rebound) drive plate tectonic motion and ultimately volcanism.
2. The radioactive substances inside the earth keep generating a lot of heat through decomposition and chemical reactions. As a result the material in the earth's interior is in constant flux. This molten, semi-molten and sometimes gaseous material appears on earth at the first available opportunity.

6.7 DISTRIBUTION OF VOLCANOES

The distribution of the present day volcanoes are restricted mostly to the mobile-zones of the earth's crust. Of course there are certain exceptions as for example, there are no volcanoes in the Himalayas and there is no sign of recent-folding in Iceland.

The most important belt of volcanoes is the so-called Ring of Fire or the Circum-Pacific belt where more than 60 percent of the active volcanoes are located. It extends through the Andes of South America, Central America, Mexico, and the Cascade Mountains of western U.S.A., the Aleutian Islands, Kamchatka, the Kurile Islands, Japan, Philippines, New Guinea, Solomon Islands, New Hebrides and New Zealand. Volcanoes like Cotopaxi, Katmai, and Fujiyama etc. are located in this belt.

Another belt runs north-south through the Atlantic and accordingly is known as Atlantic belt. It extends, from Jan Mayon Island in the north, through Iceland, the Azores and the Canary Islands to the Cape Verde Islands in the south. Volcanoes like Mt. Pelee, St. Helena, Mt. Hekla, Mt. Helgafel etc. are located in this belt.

Another volcanic belt is the Mediterranean Himalaya belt extending east-west from the Alps via the Apennines to the Caucasus and the mountains of Asia Minor. Volcanoes like Vesuvius, Etna, Mount Ararat and those of the Lipari Islands are located in this belt.

In our country **India**, only one volcano exists in Andaman Islands located in the **Barren Islands**, it is dormant, however it was erupted in 2017 with the mild eruptions of ash.

6.8 SUMMARY

Volcanoes are the conical or dome shaped structures built by the emission of lava and it contained gases from a restricted vent in the earth's surface. Volcanoes may vary in size from small conical hills to some of the lofty mountains on the earth surface. The molten rock material, if it is within the earth crust is called magma; if it comes out through volcanic vent it is called lava. The product of volcanic eruption consists of gases, rock fragments and lava. The gases are mainly CO₂, H₂, CO, S and Cl. The rock fragments are classified based on their size as volcanic bombs, cinders or lapilli, ash, fine ash, tuff and volcanic dust. The lavas are called block lavas. Volcanic eruptions are divided into two types central eruptions and fissure eruptions. Majority of the present day ones are of central type. Deccan basalts are best example for fissure eruptions. The important volcanic types are shield volcano, cinder cones, composite cones, calderas, fissure eruptions. When highly viscous lavas are extruded, the volcano takes the

shape of a dome and is called shield volcano. Cinder cones are built of cinder and ash and generally have the form of truncated cone with a crater at its top. Intermediate in form between the steep cinder cones and flat domes of shield volcanoes are the composite cones. Calderas are usually large craters with huge circular pit due to the explosive eruption of former volcano. If the volcanic materials are extruded from the cracks of the earth crust, it is called fissure type. Based on the degree of explosive activity and nature of eruption, volcanic activity is classified as **Hawaiian** type, **Strombolian** type, **Volcanian** type, **Vesuvian** type, **Plinian** type and **Pelean** type.

The causes for volcanism are the release of pressure from the magma chamber under the ground surface, radioactive heat in the magma, frictional heat in the magma and increase of heat with depth.

6.9 CHECK YOUR PROGRESS-MODEL ANSWERS

1. The name volcano is generally applied to the surface form which develops around a central vent which may be an orifice or a fissure through which hot incandescent magmatic materials are continuously or intermittently ejected.
2. The pyroclastic material is classified based on their sizes.
 - a) Blocks-larger than 32mm
 - b) Bombs-ejected as clots and somewhat rounded
 - c) Lapilli or cinders- the size between 32mm to 4 mm
 - d) Ash: The size between 4mm to 1/4mm.
 - e) Fine ash or volcanic dust: smaller than 1/4mm.
3. The layers of lava and pyroclastic material sloping down in all direction from the volcanic vent and are often found to have radiating dykes penetrating through them such volcanoes are called Strato volcanoes
4. Hawaiian, Strombolian, Volcanian, Vesuvian, Plinian and Pelean types of volcanic activity.

6.10 MODEL EXAMINATION QUESTIONS

I. Answer the following questions in 30 lines.

1. Describe the types of volcanic cones and explain how they are build up.
2. Give an account of the products of volcanic eruptions.
3. Mention briefly about different phases of volcanic activity.

II Answer the following questions in 10 lines.

1. Give brief account of the types of volcanic eruptions.
2. Write down the distribution of volcanoes.
3. Describe causes of volcanism.

