UNIT 14 GEOLOGICAL HAZARDS

Structure

14.0 INTRODUCTION

You have been introduced to natural hazards in the previous unit. In this unit we will discuss about the geological hazards, their geographical distribution and impact on mankind. Geological processes such as earthquakes, volcanism, mass movements (commonly referred to as landslides) have always worried mankind due to the hazards they cause. Earth scientists have been continuously trying to evaluate the causes of these natural geological processes. The success in this regard is partial; nevertheless, they are successful in delineating vulnerable spots/places on earth which are prone to such natural calamities.

Earthquake in simple words means shaking/trembling of the ground/earth's surface. It is one of the deadliest natural disaster which has caused enormous loss of life and property in the last century. The Bhuj earthquake of 2001 rocked the parts of Gujarat is an example of vast destruction caused by an earthquake. ***Volcano*** is the result of upsurge of molten material along with dissolved gases from generally upper mantle depths onto the surface of the earth. The source of this molten material lies in the

asthenosphere (part of molten mantle). A dreadful example of volcanic fury which is also commonly quoted in school books is of Pompeii. It is an ancient town of Italy was destroyed by a volcanic eruption in 79 AD, killing all its inhabitants. The town was buried under the volcanic ejecta from the eruption of Mount Vesuvius. The archaeological excavation of the Pompeii, now a UNESCO World Heritage Site, records the ruins of this lost city to a volcanic eruption. ***Massmovement*** which is commonly referred to as ***landslide****or* ***mass wasting,*** is movement of large quantity of rock mass and loose material along the slopes of the mountains and hills. This natural hazard is quite common in mountainous regions which commonly experience earthquakes and volcanic activity in addition to heavy downpour and anthropogenic activities. Human activities in mountainous areas include mountain cutting using explosives for making roads, constructing a dam for embankment of river water etc). The rocky material moving downslope can destroy anything which comes its way.

14.1 OBJECTIVES

After studying this unit, you should be able to:

- Describe the geological processes like earthquake, volcano and mass movement;
- Discuss the types and causes of geological processes like earthquake, volcano and mass movement;
- Describe the geographical distribution of earthquake, volcano and mass movement;
- Explain the impact of earthquake, volcano and mass movement on human beings and environment.

14.2 TYPES AND CAUSES OF GEOLOGICAL HAZARDS

You have been introduced to earthquake, volcano, and mass movement in the previous section. Now let us discuss the types and causes of these three geological hazards.

14.2.1 Earthquakes

Earthquake means quaking or shaking of the earth. The lithosphere comprises crust and uppermost part of mantle. It isthe earth's rigid part and is made up ofnumerous tectonic plates which are in motion with respect to each other. Lithospheric plate can be continental and oceanic. Oceanic crust being denser undergo subduction. The movement of these tectonicplates over the ductile asthenosphere are responsible for causing earthquakes.

The plate boundaries are an outcome of interaction of plates which are of three types:

1. Divergent Plate Boundary: It is also known as constructive plate boundary because new oceanic crust is formed on the either side of the ridge and two lithospheric plates move away from eachother.

1. Convergent Plate Boundary: It is also known destructive plate boundary because when plates move towards each otherthe lithospheric plate is destroyed at this boundary.

2. Transform Faults: It is also known as conservative plate boundary because neither the crust is created nor destroyed. The two plates slide past each other. Numerous transform faults offset the mid oceanic ridges.

Themovement of tectonic plates indicate play of enormous stresses. The plate boundaries/margins manifest these stresses in form of earthquakes and volcanoes. The upper crust comprising brittle rocks tend to fail under enormous stresses built up at plate margins and results in faulting/breaking of rocks. Earthquakes are triggered by faulting as it results in displacement of rocks along the fault.Earthquake releases energy in form of seismic waves which trigger outwards from the focus of the earthquake. The seismic waves are of three types viz.: ***P waves*; *S waves*** and the ***Surfacewaves***. Surface waves are the most destructive waves and are responsible for the loss of life and property during an earthquake.

(A) Types of Earthquakes

Earthquakes can vary in size, type and effect depending on factors like:

- Tectonic setting
- Bedrock
- Overlying unconsolidated material
- Building codes
- Presence or absence of groundwater

Now you will read about the types of earthquakes. Based on depth of their origin, earthquakes may be broadly classified into three types:

(i) Normal or shallow depth earthquakes originate from within a depth of 50 km.

(ii) Earthquakes of intermediate depth originate at a depth of 50 to 240 km.

(iii) Deep-focus earthquakes originate at a depth of several hundred kilometres (240 to725 km).

(B) Causes of Earthquakes

Now you might be wondering why the Earth shakes and what causes the earthquakes?

Let us discuss the causes of earthquake. They can be placed into the following three groups:

1. **Surface Causes**: They produce earthquakes of minor intensity which are often insignificant and are caused due to:

(i) Collapse of Caves: The caves and cavities are formed by the action of underground water in the rocks like limestone. The impact in the surrounding area may result in their collapse causing feeble earthquake.

(ii) Landslides/mass movement/mass wasting: Massive landslide often causes shaking in the surrounding area.

(iii) Blasting of rocks: This can generate tremors in surrounding area which may produce cracks in the houses or induce landslides.

2. **Volcanic causes:** The earthquakes associated with volcanoes are more localised both in extent of damage and in wave intensity produced.

3. **Tectonic Causes:** They include most important causes for major earthquakes. Some of these are:

(i) Plate Tectonics: The crust of the Earth is divided into plates which may be continental, oceanic, or combined. Movement of these plates produces earthquakes. In most of the cases the earthquakes are disastrous.

(ii) Movement along Fault planes: Crustal displacements or structural disturbances cause sudden slipping of the Earth's crust along the faults. As a result of movement of the adjacent blocks of fault, major earthquakes are produced.

(iii) Elastic Rebound Theory: This describes the mechanism by which earthquakes are generated. Elastic Rebound theory was propounded by Harry Fielding Reid after studying 1906 San Francisco earthquake faultline. According to him the materials of the Earth, being elastic, can withstand a certain amount of stress without deforming permanently but if stress is continued for a long period of time or if it is increased in magnitude, the rocks will undergo permanent deformation or strain and eventually rupture. When the rupture occurs, rocks on either side of the fault tend to return to their original shape-position because of their elasticity and an elastic rebound occurs. In nutshell, you can learn that the Elastic-rebound theory is a concept that accounts for the earthquakes generated by the sudden slippage of rocks on either side of a fault plane. In this process, the rocks release the strain energy which has been gradually accumulated and attempts to return to an unstrained condition.

14.2.2 Volcanoes

Volcano may be defined as any landform that releases lava, gas or ashes or has done so in the past. The geologic processes that give rise to volcanoes and volcanic rocks are collectively known as *volcanism*. Magma, the molten rock is liquid; it is less dense than the rocks that produce it. Therefore, as magma accumulates and begins to float upward, finding a path to the surface by fracturing lithosphere along the zones of weakness. In some places, magma eventually reaches the surface and erupts as lava. Hot materials escape from an opening called *vent* or *fissure*(Figure 14.1). These vents and fissures are the volcanoes through which hot molten materials are ejected regularly (active) or intermittently (dormant). The passage through which the molten materials are ejected is the volcano. It may appear on the surface through same fissure called *fissure type* or through a single opening where it assumes shape of a cone called *cone* or *crater type*. If eruptions have ceased, it is extinct volcano, which was active in the past.

Figure showing distribution of Deccan plateau. At the end of the Cretaceous period, 65 million years ago, volcanic eruptions created the Deccan Plateau that covers most of southern India.

Scientists estimate that at least 500 million of the total world population is at risk from volcanoes. Millions of people are vulnerable to the effects of dangerous eruptions. Therefore, it is important to improve our understanding of the volcanoes and how they work. *Volcanology* also improves our understanding of Earth's interior.The Volcanic Explosivity Index (VEI) was devised by Chris Newhall of the US Geo-logical Survey and Stephen Self at the University of Hawaii in 1982 to provide a relative measure of the explosiveness of volcanic eruptions.

The Nevado Ojos del Salado mountain is the highest volcano (6900 meters) on earth and is located in South America along the Andes mountain on the Argentina-Chile border. It also records the highest crater lake of the world.

Explosive eruptions -Lavaswith high gas contentsand viscosity

Subdued eruptions –Lavas with low gas contents and viscosity.

Fig. 14.1: Saint Helen's explosive volcano.
(Source:https://volcanoes.usgs.gov/volcanoes/st_helens/st_helens_multimedia_gallery.html)

Mount St. Helens, an active explosive stratovolcano in US, ispart of the Cascade Volcanic Arc. It is part of Pacific Ring of Fire that is known for over 160 active volcanoes. Mount St. Helens is popularly remembered for its 1980 eruption. It caused destruction and devastation in the adjoining areas causing death of around 57 people and rendering many homeless. It also destroyed infrastructure of the area within a radius of approximately 300 kms from the eruption site.

Fig. 14.2: Kîlauea Volcano's summit in Hawaii.
(Source:https://volcanoes.usgs.gov/volcanoes/kilauea/multimedia_chronology.html)

Kîlauea, an active shield volcano of Hawaiian Islands, is an outcome of the Hawaiian hotspot. Kîlauea in Hawaiian language means "spewing" or "much spreading" and is thus true for this frequent outpouring volcano. Most eruptions have occurred at the volcano's summit and are effusive.

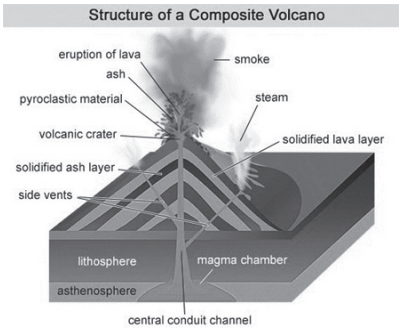

Fig. 14.3: Structure of a common explosive type stratovolcano. Also seen are its components: magma chamber (part of the asthenosphere); the conduit (passage through which the magma rises upwards); steam; volcanic crater (mouth of the volcano); side vents; ash layers; ash; smoke; pyroclastic material

(A) Types of Volcanoes

Now you will read about the classification of volcanoes based on several features.

A. Based on their activity, volcanoes are classified into following three types:

- *Active Volcanoes:* A volcano is active when it is erupting intermittently or continuously
- *Dormant Volcanoes:* These are the volcanoes which show eruptions with a lapse of considerable period.
- *Extinct Volcanoes:* These are those volcanoes which have not shown any volcanic activity within recorded period of history.

B. Based on the mode of eruption volcanoes are classified as:

- *Central types*: In this the products escape through a single vent or pipe. The magma is more viscous in Central type volcanoes and tends to build a volcanic landform on the flanks of its central vent (as shown in Fig. 14.3).
- *Fissure Icelandic Type:* The lava comes out slowly through fissures. It flows to distances covering large areas being less viscous or more fluid (as shown in Fig. 14.3). The lava flows of *Deccan traps* in central and southern India are of same type.

C. Based on nature of eruption, volcanoes may be of two types:

- *Explosive Type:* In this case, the lava is of acidic nature and because of their high degree of viscosity they produce explosive eruptions.
- *Quiet type:* In this case, the lava is of basaltic composition, which is highly fluid and holds some gas. As a result, the eruptions are quiet and the lava can travel long distances to spread as thin layers.

D. Besides the above, several other types of volcanoes have been identified according to their degree of explosive activity and nature of eruption. They are:

- **Hawaiian Type**: Mildest with no explosive activity. Lava is mobile and less viscous, so it spreads out. Little drops of lava form thread like masses blown up by wind called Pele's hair. Large quantities of gasses discharge quietly.For example-Hawaiian volcanoes.
- **Strombolian Type**: This type of volcanism is at times violent and explosive. Lava is more viscous, and the fragments of lavas are blown up into air forming bombs and scoriaceous fragments. For example-Volcano Stromboli in Sicily.
- **Vulcanian Type**: It is sometimes explosive. Lava is very viscous, solidifies quickly. Huge quantity of rock fragments are blown during successive eruptions. Huge quantities of gases rise upwards vertically like cauliflower. Example-Vulcano in Lipari, Sicily.
- **Vesuvian Type**: It is highly explosive. Magma explodes as result of high gas content, which ascend in cauliflower like column of gases with lots of fragmental materials. For example-Vesuvius near Naples.

- **Pelean Type**: It is most violent type of volcanism. Magma is highly viscous and forms hard cover in the form of volcanic pipes. The escape of gases takes place through sides of volcanic cone as avalanche of molten rock material and gasses. Mont Pelee, Martinique, West Indies.

- **Plinian Type**: This shows extremely violent type of volcanism. Many gases and volcanic ejecta rise in column to great heights like cauliflower. Huge fragmental products are produced with no discharge of lava. For example-Pompeii, Rome.*Plinian type* is the name given after Pliny, the younger, who in his letters to Tactius, described an explosion of the Vesuvius that caused the destruction of cities of Pompeii and Herculaneum.*Volcanic eruption* on May 8, 1851, killed 40,000 people in Pelee.

(B) Causes of Volcanoes

Let us now read the causes of volcanism. Although the scientists are trying to investigate the ultimate causes, some of the basic probable causes are given as follows:

i. You have read that interior of the Earth is very hot. Water vapours and hot molten magma move towards the surface through low pressured weak planes. Release of high pressures, which build-up within magma chamber causes eruption of the volcanoes on Earth's surface.

ii. Accumulation of radioactive heat produces magma. This molten material ultimately comes out in form of volcanoes.

iii. Friction and fault movements at greater depths may cause melting and forcing of the molten material to the surface.

iv. You will read in the previous section that the Earth's lithosphere is divided into several plates. These plates move in different directions with respect to each other. When these plates converge, one of the plates moves below the other. On the margin of the subsiding plate melting takes place and the molten material is thrown out forming chain of volcanoes parallel to plate boundary. For example, the Himalaya, at the boundary of the dynamic Indian plate that subducts below the relatively static Asian plate.

14.2.3 Mass-movement

Mass-movement or mass wasting is an outcome of weathering and erosion taking place along the mountain/hill slopes. The weathering agencies such as water (rainfall, glaciers, streams etc.), wind, gravity are largely responsible for various types of mass-movement.Popularly, a layman identifies any type of mass-movement as a landslide.Various types of mass movements have been documented in the literature based on their peculiar characteristics. Earth scientists commonly attribute mass movements based on the following parameters:

a. Nature of the bedrock which gets weathered. For example, the degree and nature of weathering is unique for each rock type. It is controlled by the physical and chemical properties of the individual rock type. For example, the granite rock which is hard and massive will take much longer periods to weather compared to foliated and mica rich rock types. The foliated, mica rich rocks are thus liable to mass-movements if the hill slopes are made up of these rocks.

b. The consolidated/unconsolidated material ratio largely dictates the type of mass-movement.

c. The speed of the natural agenciesresponsible for mass-movements viz. glaciers, rainwater, gravity etc dictate the rate of mass-movements. The mass-movements can vary from very slow movements i.e. a few millimetres in years to very rapid movements i.e. many kilometres per hour.

d. The slope angle is very important as it dictates whether theweathered materials fall, slide, or flow under various conditions.

e. Besides the above discussed natural geological factors, anthropogenicactivities likeexcavation for tunnels, road building etc are responsible for acting as triggers for various types of mass-movements.

f. Other geological phenomenon such as earthquakes, volcanoes commonly triggers mass-movements. Numerous examples are documented in the past where mass-movements have occurred due to earthquakes and volcanism.

(A) Types of mass movement

Mass movement or mass wasting is classified based on rate of movement and type of material which slides down the slope. It is more generalised term and includes almost all types of slides and flow. Some of the important types and processes involved in mass wasting are given below:

Rockfall occur when an accumulation of consolidated rock fragments is dislodged and falls through the air or free falls vertically under the influence of gravity, rapidly from a cliff or by leaps down a slope.

Debris falls are similar to rockfall except that they involve a mixture of soil, regolith, vegetation and rocks.They are commonly referred to as landslide.

Rockslide results when a slope fails along the plane of weakness. Debris slide is characterised by unconsolidated rock, debris and regolith. While rockslide lacks typical debris; usually, it consists of blocks of rock in a chaotic mass. The rapid sliding descent of a rock mass down a slope commonly forms heaps and confused irregular masses of rubble at the base of the mountain or hill.

Slump is the sudden downward slipping of rock block or regolith along a curved surface of rupture. The movement creates a scarp facing downslope.Slump is particularly common in places where slopes are steep and cliff like by erosion at their bases as along stream banks and coastal cliffs.

Mudflow is a debris flow which is principally composed of mud and is saturated with water. It can travel several tens of kilometers from their source.

(B) Causes of mass movement

The causes of mass movement are as follows:

- earthquake shocks
- blasting for quarrying or construction, *etc.*
- absence of surface drainage, increasing water percolation and ultimate sliding

- presence of more joints and cracks in the rocks
- steepening of slope for various purposes
- slope saturated with water because of bad drainage
- increased height of slope because of quarrying, mining, *etc.*
- extra load of dams, buildings, townships, *etc.* placed on slopes.

Mass movement can be hazardous if humans (or their buildings and roads) are in the way. Anthropogenic activities may reduce the stability of regolith and rock leading to mass wasting.

Check Your Progress 1

Note: a) Write your answer in about 50 words.

b) Check your progress with possible answers given at the end of the unit.

1. Name the most destructive seismic wave.

.....

.....

.....

2. Give one example each of Plinian and Hawaiian volcanism.

.....

.....

.....

3. Draw a picture of stratovolcano and label its parts. Give one example of stratovolcano.

.....

.....

.....

4. Describe different types of plate boundaries and give examples.

.....

.....

.....

14.3 GEOGRAPHICAL DISTRIBUTION

Mostly earthquakes originate at the plate boundaries as has been discussed in the preceding section on earthquakes. Earthquakes are also recorded within plates i.e. intraplate earthquakes which are shallow focus (< 30 km).Mid ocean ridges, characteristic of divergent plate boundaries, record shallow earthquakes with focus < 50 km. The transform-fault boundaries,where lithospheric plates slide past each other,

record high incidence of earthquake activity in comparison to mid ocean ridges. The convergent plate boundaries record the largest (in terms of magnitude)and deepest (>600 km deep focus) earthquakes earthquakes of Circum - Pacific Belt).The earthquakes which occur at convergent plate margins can also lead to Tsunamis which can cause large scale destruction along coastlines and landwards.

Tsunamis are large sea waves which can be generated by displacement of seafloor initiated by large earthquakes affecting seafloor. Tsunamis are also triggered by large scale landslides and volcanic eruptions.

The volcanoes in common with earthquakes, mostly originate at plate boundaries. The volcanoes are also common along intraplate settings (i.e. plume activity and rift zones).The most active volcano of the world, Kilauea Volcano of Hawaii, has formed because of intraplate volcanism/hot plume activity. There is a relationship between the volcanoes vis-à-vis subductionzones (convergent boundaries), mid-oceanic ridges (divergent boundaries), transform plate boundaries and hot spots (plume activity).Landslides are geographically distributed along mountainous belts of the world. The mountain slopes become unstable due to various factors such as:

i) Tectonic activity;

ii) Earthquakes;

iii) Volcanism;

iv) Various forms of precipitation (snow, rainfall, flash floods; heavy downpour, lake bursting etc); and

v) Anthropogenic activities (mountain cutting, tunnel making, dam construction etc.).Most landslides are controlled by the relief of a region. The relief further depends on the tectonic uplift rates. The precipitation in various forms further triggers landslides. For example, the southern part of Himalayan belt which receives heavy rainfall experiences number of landslides every year. The arid portions of central Andes do not commonly experience landslides inspite of its elevation owing to restricted downpour.The landslides prone areas include the: southernmost part of the Himalayan Arc, coastal areas of southwest India, south and east coasts of China, western edge of the Philippine sea plate, central Caribbean islands, mountains in Central and South America covering parts from Mexico Chile, the island of Java in Indonesia and some regions along the Alps (Petley, 2012).

Check Your Progress 2

Note: a) Write your answer in about 50 words.

b) Check your progress with possible answers given at the end of the unit.

1. What is a Tsunami?

.....

.....

.....

2. Name one volcano formed because of intraplate activity.

.....

.....

.....

3. Discuss the global distribution of volcanic activity.

.....

.....

.....

4. Where do deep and shallow earthquakes originate on earth?

.....

.....

.....

14.4 IMPACT ON LIFE, PROPERTY AND ENVIRONMENT

The geological hazards such as earthquakes, volcanoes and landslides impact the people, property, and environment in their vicinities. Theimpacts of these hazards are briefly discussed below.

14.4.1 Impact due to Earthquakes

The earthquakes were alone responsible for deaths of around2 million people in the last century (Grotzinger and Jordan, 2014). The deadliest earthquakes in the past 15 years (the 2004 Sumatra earthquake, Indonesia; the 2011 Tohuku earthquake, Japan; the 2001 Bhuj earthquake, India, the 2015 Nepal Earthquake) have caused enormous destruction in terms of life and property. The economy of a country is also affected by the impact of a high magnitude earthquake (ExampleJapan earthquake, 2011). The earthquakes also lead to tsunamis, landslides, avalanches etc. This also can cause collapse of manmade structures (buildings, dams, nuclear power plants etc). The collapsing of man-made structures also leads to loss of life and property. The densely populated earthquake prone zones are the worst affected as the maximum destruction is caused by failure of infrastructure. The infrastructure failure causes burial of people and other life forms under the rubble. The magnitude of loss of life and property increases many folds during high magnitude earthquakes in countries which do not adopt building codes for construction purposes. The earthquakes are also commonly responsible for triggering landslides. The ***liquefaction*** (water saturated ground starts to flow like liquids) is common during an earthquake and itresults in destruction of buildings, bridges etc. The gas lines, electric poles, petrol pumps might get ruptured leading to fires and cause havoc in thickly populated regions during earthquakes. The earthquakes also trigger firebreaks, leak of nuclear material etc. This kind of hazard was experienced during the Japan's 1923 and 2011 earthquakes. Example of Kanto earthquake of Japan in 1923 led to loss of .14 million lives due to fire in the cities of Tokyo and Yokohama triggered by an earthquake.

14.4.2 Impact Due to Volcanoes

In present times, it is possible to a certain extent to figure out world's dangerous and

most active volcanoes. We can assess their present hazard potential by studying the earlier patterns and the variety of deposits laid down by these active volcanoes during previous eruptions. Presently, 100 high-risk, active volcanoeshave been identified globallyout of which 50 volcanoes erupt every year. To understand the hazard caused by any volcanic eruption it is imperative to know the type of volcano.Volcanoes depending on their degree of explosiveness vary in their destructive power. Some volcanoes are explosive and destroy the surroundings in its vicinity up to a few kilometres. Whereas, the non-explosive or effusive volcanoes don't cause casualties due to their nature of eruptions. The explosive volcanoes are the most harmful ones to the environment and to life. The explosive volcanoescan produce fragmental rocks, volcanic ash,pyroclastic flows and surges, debris avalanches, lahars, and landslides.An erupting volcano is also responsible for release of gases, tephra, and heat into the atmosphere.

The volcanic eruptions lead to escape of lot of poisonous gases into the atmosphere. The various gases are carbon dioxide (CO_2), sulfur dioxide (SO_2), hydrogen sulfide (H_2S), hydrogen fluoride (HF), hydrochloric acid (HCl), carbon monoxide (CO), hydrogen gas (H_2), methane (CH_4), besides water in the form of steam. These gases spewed out of the volcanoes are hazardous to life forms (people, animals and vegetation)depending on their concentration in the atmosphere. For example, CO_2emitted from volcanoes can get diluted after mixing with the atmospheric gases and is not life threatening. But if the concentration of CO_2 is more than 3%, it can lead to headaches, dizziness, increased heart rate and respiratory problems in humans.Similarly, high concentrations of CO_2 gas in soils can adversely affect vegetation. SO_2 emissions also are responsible for acid rain and volcanic smog (VOG), which are hazardous for various life forms.When SO_2 reaches stratosphere (altitudes>10km), it is converted to sulfate aerosols which are also responsible for ozone depletion. H_2S is very toxic and can create respiratory problems and lead to pulmonary edema. Halides (HF, HCl, HBr) are strong, toxic acids and can cause acid rain in areas in the vicinity of volcanic eruptions. The ash particles can get coated with these hydrogen halides and can cause pollution of drinking water supplies and crops to alarming levels.

The report of fatalities due to lightning from volcanic eruption clouds is common. Volcanic ash disrupts electricity and telephone communication lines thus causing inconvenience to people in the affected areas. Volcanic ash is a big hindrance for the air traffic and is a hazard for the aviation sector. It damages machineries, causes fire outbreak, clogs drainage and sewage systems. Ash suspended in the atmosphere reduces visibility and is a major cause of respiratory problems in humans and animals.Tephra, an outcome of volcanic eruptions, destroyscrops and vegetation and can cause famine. Lava flows are very hot (550^{o}C-1400^{o}C) and can cause serious burn injuries. Lava flows being hot can quickly melt snow and ice and produce floodingand also lead to glacier bursts. Lava flows can probably dam rivers and can cause local flooding of the areas in its vicinity. Pyroclastic surges can be extremely dangerous and can cause burial, burning and suffocation since it contains hot material and toxic gases. Estimated 30,000 people were killed due to pyroclastic surges in 1902 from Mount Pelee in the town of St. Pierre part of Lesser Antilles island arc of the Caribbean. Pyroclastic flowsowing to their high temperatures can cause destruction of manmade structures, vegetation and various life forms caught in them.Lahars contain more water in comparison to pyroclastic flows. Lahars are catastrophic for people inhabiting valley areas proximal to volcanic eruptions.Lahars can be quite destructive and lead to

destruction of infrastructure (buildings, roads, bridges etc) by burying them under it.The lahars can grow in volume by consuming more water and adding more material to it when it moves downslope. They manifest in forms of landslidesand can damage river valleys and flood plains. Large lahars can cause destruction of property and loss of life.Approximately, 0.2 million people have been killed due to volcanic eruptions and their aftermath during the past 500 years. The main reason of loss of life is the population increase along the flanks of volcanoes and along the valley areas near them.

14.4.3 Impact Due to Mass-movement

The massmovements can be triggered by various factors such as high relief, heavy downpour, and tectonic instability of a region (volcanism and earthquakes). The details have been discussed in the section onmass-movements at the appropriate place. However, the thickly populated areasin combination with the above factors experience the most fatal landslides. Anthropogenic activities also trigger mass-movements.The hazards posed bymass-movementare numerous. The mass-movements can continue for days and years and travel long distances and can destroy everything that comes their way. The mass-movements can block rivers and lakes and cause flooding. The lahars produced by mixing of debris with large amount of water can disrupt life of people living in valley areas.Landslides cause loss of property and death and injury to people stranded on roads or hill slopes during landslides. It also causes disruption of roads, bridges and is common in hilly terrains in India. The secondary effect of this is also total disruption of life in far flung rural areas where eatables and goods reach by roadways. It is a common problem in the mountainous regions in India

Check Your Progress 3

Note: a) Write your answer in about 50 words.

b) Check your progress with possible answers given at the end of the unit.

1. Give one example of devastating earthquake from India.

   .....

   .....

   .....

2. What are pyroclastic surges?

   .....

   .....

   .....

3. Are landslides common in India?

   .....

   .....

   .....

4. What are the adverse effect of mass movement on human beings?

.....

.....

.....

5. Do volcanoes affect environment. If yes, Explain.

.....

.....

.....

14.5 CASE STUDIES

Now let us study about some case studies pertaining to geological hazards.

14.5.1 Case Studies on Earthquakes

Earthquakes are common in regions experiencing tectonic activities. They may occur along the plate boundaries as well as within the plate. India has witnessed many earthquakes in the past century, and we will take up a case study of Bhuj earthquake in this section. The Bhuj earthquake of Gujarat state, shook almost the whole of India around 8.40 am on 26thJanuary, 2001. It measured 7.7 on the Richter scale and was one of the deadliest earthquakes India has witnessed in the last two decades.This earthquake killed around 20,000 people. The earthquake was so intense that it destroyed many towns and villages in the vicinity of Bhuj. Bhuj town saw the maximum destruction and the other town which were severely damaged were Anjaar, Vondh and Bhachau. Several buildings in these places were demolished due to the earthquake and also led to deaths of large population due to burial in the rubble.This earthquake rendered many people homeless. It caused injuries to approximately 167,000 people. Many historical buildings (Swaminarayan temple, Prag Mahal, Aina Mahal), tourist places, hospitals, school, infrastructural facilities were destroyed during this earthquake. The Indian National Trust for Arts and Cultural Heritage surveyed around 250 heritage buildings in Kutch and Saurashtra to assess the damage caused to them during the Bhuj earthquake. It was reported that about 40% of these heritage buildings were completely or partially destroyed during the earthquake. In Ahmedabad approximately 50 multi-story buildings collapsed killing hundreds of people. Total loss of life and property was enormous and 16 years later the state is still recuperating from the fury of the Bhuj earthquake which knocked down the once prosperous state of India.

14.5.2 Case Studies on Volcanic Activity

We donot have volcanic eruptions in India and thus we will take a case study from the Circum-Pacific zone. We will discuss the catastrophe caused by the eruption of strato volcano Mount Pinatubo of Phillipines on 15thJune, 1991. This has been recorded as the second-largest volcanic eruption in a densely populated area of Phillipines. The volcaniceruption led to high-speed avalanches, ejection of gases and ash flows, giant mudflows. Hundreds of miles in the neighbouring areas were covered with volcanic ash clouds. Volumes of volcanic ejecta in form of ash, pumice fragments and pyroclastic flows moved down the slopes of Mount Pinatubo and filled the adjoining valleys with

volcanic materials forming 200 meters thick volcanic deposits. The wet ash settled on the roofs of the dwelling units and collapsed them under its weight. Ash material got hydrated and remobilised by monsoon and typhoon rains and formed mudflows and lahars causing enormous destruction than the eruption itself. The timely prediction from the Philippine Institute of Volcanology and Seismology and the U.S. Geological Survey together saved approximately 5,000 lives and at least $250 million worth property. Aviation sector suffered a loss of $100 million due to the thick ash clouds. About 20,000 indigenous population inhabiting the slopes of the volcano, were relocated. The cultivated farmlands were buried under lahars. Many villages and towns in the vicinity of Mount Pinatubo were buried under the lahars. A total loss of 800 people was reported from this deadliest volcanic eruption.

14.5.3 Case Studies on Mass-movement

India has recorded numerous landslides in the Himalayan region and along the Western Ghats. These landslides are common during monsoon period i.e. July-September. We will take up a case study of the 2010 Ladakh landslide caused by heavy rains and floods, quite unusual for this region. The floods due to heavy deluge occurred on 6 August 2010 covering most parts of Ladakh. Ladakh is part of state of Jammu and Kashmir. Ladakh region is 'high altitude cold desert' (3500 meters above sea level)with paucity of rainfall (around 100 mm/yr). The heavy rains of 6th August 2010 were quite unusualand it triggered flash floods, followed by mudflows and debris flow. The heavy rainfall, flood and landslide affected approximately 9000 people in the region. Total of 71 towns and villages were completely to partially destroyed including Leh, claiming lives of around 255 people. Thousands were rendered homeless due to the floods, debris and mud flows. In Leh alone, the infrastructure collapsed damaging buildings, hospitals, main bus station, telephone and mobile-phone towers, radio station transmitter were destroyed. The destruction was enormous and was mainly caused by debris flows from the adjoining rocky slopes of the valleys. There were reports of buses damaged and dragged over a mile by the mud flows. Many small villages (Sobu, Phyang, Nimmu, Nyeh, and Basgo)suffered destruction on account of torrential rain and rain induced debris flow.

14.6 LET US SUM UP

The earthquakes, volcanoes and mass movements are natural geological processes which are hazardous to the people and the environment. These natural geological processes are boundto occur, but if managed well the destruction caused by them could be minimised. To date enormous understanding about the causes of these natural phenomenon's have been documented. However, it is yet not possible to predict with certainty the location and time of an earthquake, volcano and landslide.The plate boundaries are the locations where most earthquakes andvolcanoes originate. Mass movement occurs in mountainous regions. These cannot be prevented, but their devastating effects can be minimised by a combination of scientific and conscience government and public policies.

14.7 KEYWORDS

Asthenosphere : Zone of Earth's mantle lying beneath the lithosphere and believed to be much hotter and

more fluid than the lithosphere. The asthenosphere extends from about 100 km (60 miles) to about 700 km (450 miles) below Earth's surface.

Lithosphere : Rigid, rocky outer layer of the Earth, consisting of the crust and the solid outermost layer of the upper mantle. It extends to a depth of about 60 mi (100 km). It is broken into about a dozen separate, rigid blocks, or plates.

Tephra : When a volcano erupts it will sometimes eject material such as rock fragments into the atmosphere. This material is known as tephra.

Blocks and Bombs : The largest pieces of tephra (greater than 64 mm) are called blocks and bombs. Blocks and bombs are normally shot ballistically from the volcano (refer to the gas thrust zone described in the direct blast section).

Liquefaction : A process by which water-saturated sand, soil act as a fluid caused by an earthquake shaking.

Pyroclastic flows : Fluidized masses of rock fragments and gases that move rapidly in response to gravity.These are denserthen pyroclastic surges and can contain as much as 80 % unconsolidated material

Stratovolcano : Also known as a **composite volcano,** is a conical volcano built up by many layers (strata) of hardened lava, tephra, pumice, and volcanic ash. Unlike shield volcanoes, stratovolcanoes are characterized by a steep profile and periodic explosive eruptions and effusive eruptions**.**

Shield volcano : Is a type of volcano usually built almost entirely of fluid lava flows. This is caused by the highly fluid lava they erupt which travels farther than lava erupted from stratovolcanoes. This results in the steady accumulation of broad sheets of lava, building up the shield volcano's distinctive form.

14.8 REFERENCES AND SUGGESTED FURTHER READINGS

Grotzinger, J.P. and Jordan, T. H., 2014: Understanding earth. W. H. Freeman andcompany, New York. 672p.

Mount Pinatubo. (2010). *Wikipedia, the free encyclopedia*, last edited 22.23, 14 May, Wikipedia Foundation. Retrieved May 15, 2010 from http://en.wikipedia.org/wiki/Mount_Pinatubo

NASA. (n.d.) Mt Pinatubo, *Nasa Images*. Retrieved May 24, 2010 from http://www.nasaimages.org/luna/servlet/detail/NVA2~14~14~29598~124268:Mount-Pinatubo-L&C-band

Riley, C. (n.d.) Types of volcanic hazards. Retrieved May 5, 2010 from http://www.geo.mtu.edu/volcanoes/hazards/primer/

Petley (2012). Global patterns of loss of life from landslides, Geology, vol 40 (10), 927-930.

14.9 ANSWERS TO CHECK YOUR PROGRESS

Your answers should include the following points.

Answers to Check Your Progress 1

1. Surface-waves
2. Mount St. Helens an example of explosive volcanism whereas Kilauea Volcano is an example of effusive volcanism.
3. Answer from section 2.2.2 and explain.
4. Take answer from section 2.2.1.

Answers to Check Your Progress 2

Your answers should include the following points.

1. Tsunamis are large sea waves which can be generated by displacement of seafloor initiated by large earthquakes affecting seafloor. Tsunamis are also triggered by large scale landslides and volcanic eruptions.
2. Kilauea Volcano of Hawaii.
3. The volcanoes in common with earthquakes, mostly originate at plate boundaries. The volcanoes are also common along intraplate settings (i.e. plume activity and rift zones). The most active volcano in the world, Kilauea Volcano on the big island of Hawaii, is formed due to intraplate volcanic activity due to hot plume. There is a relationship between the volcanoes vis-a-vis subduction zones (convergent boundaries), mid-oceanic ridges (divergent boundaries), transform boundaries and hot spots (plume activity).
4. Intraplate earthquakes are shallow focus (< 30 km).Mid ocean ridges which are prominent features of divergent plate boundaries on ocean floor, record shallow earthquakes with focus < 50 km. The convergent plate boundaries record the largest (in terms of magnitude)and deepest (>600 km deep focus) earthquakes.

Answers to Check Your Progress 3

Your answers should include the following points.

1. Bhuj earthquake of 2001.
2. A pyroclastic surge is a fluidized mass of turbulent gas and rock fragments which is ejected during some volcanic eruptions. It is like a pyroclastic flow, but it has a lower density or contains a much higher ratio of gas to rock.

3. Yes, in mountainous regions which experience heavy rainfall.

4. The hazards that mass-movements pose are numerous. The mass-movements can continue for days and years and travel long distances and can destroy everything that comes their way. The mass-movements can block rivers and lakes and cause flooding. The lahars produced by mixing of debris with large amount of water can disrupt life of people living in valley areas.Landslides cause loss of property and death and injury to people stranded on roads or hill slopes during landslides. It also causes disruption of roads, bridges and is common in hilly terrains in India. The secondary effect of this is also total disruption of life in far flung rural areas where eatables and goods reach by roadways. It is a common problem in the mountainous regions in India.

5. Yes they do. The gases released are steam (H_2O), carbon dioxide (CO_2), sulfur dioxide (SO_2), hydrochloric acid (HCl), hydrogen fluoride (HF), hydrogen sulfide (H_2S), carbon monoxide (CO), hydrogen gas (H_2), methane (CH_4).Thesegases spewed out of the volcanoes are hazardous to life forms (people, animals, and vegetation)depending on their concentration in the atmosphere. For example, CO_2emitted from volcanoes can get diluted after mixing with the atmospheric gases and is not life threatening. But if the concentration of CO_2 is more than 3%, can cause headaches, dizziness, increased heart rate and respiratory problems in humans. Similarly, high concentrations of CO_2 gas in soils can adversely affect vegetation. SO_2 emissions also are responsible for acid rain and volcanic smog (VOG), which are hazardous for various life forms.When SO_2reaches stratosphere (altitudes>10km), it is converted to sulfate aerosols which are also responsible for ozone depletion. H_2S is very toxic and can create respiratory problems and also lead to pulmonary edema. Halides (HF, HCl, HBr) are strong, toxic acids and can cause acid rain in areas in the vicinity of volcanic eruptions. The ash particles can get coated with these hydrogen halides and can cause pollution of drinking water supplies and crops to alarming levels.