1. Earth Movements

Let's recall.

Observe the following pictures in figure 1.1 and discuss the questions in the class.

Fig. 1.1

1) What might be the reasons behind buildings collapsing in photo 1?
2) Which event is depicted in photo 2 ? What impact does it bring about in the surroundings?
3) In photo 3, what could be the reason behind the bend in the rock strata?
4) What could be the reason behind the difference in altitudes of the land and the steepness of the slope in photo 4?
5) Classify the events in the photos into sudden and slow movements.
6) Example of which of these movements is not likely to be found in the mainland of the Indian sub-continent?

Geographical explanation

Hills, mountains, plateaus, valleys, etc. are the landforms we see on the earth's surface. They have been developed and shaped by the internal and external forces. The internal processes are classified into slow movements and sudden movements.

The earth's surface changes slowly but continuously. These changes occur due to forces such as tension and compression. The internal processes cannot be observed. However, their effects may be seen on the surface. Formation of mountains and distribution of continents are related to slow movements. There are also sudden processes that operate within the crustal part. Their effects can be noticed on the

surface within a few seconds or hours. Earthquake and volcanoes are sudden movements.

Evidences of Earth Movements :

The landforms are never permanent in nature. They tend to change. There are evidences to indicate that the earth movements have taken place in the past and have affected the surface of the Earth. Some of them are:

a) After the Great Tsunami of 2004, the coast around Sumatra island rose by few centimetres.

b) The formation of three ranges in the Himalayas : the Siwaliks, the Middle Himalayas and the Greater Himalayas.

c) There is a report that says that due to volcanic eruption near Iceland an island appeared above the sea surface in November 1963. This event was witnessed by some sailors who were passing by the area.

d) Some islands such as the Megapode Island were reported to have been lost after the tsunami.

e) To the south east coast of Mumbai, near Mazgaon Dockyard, there are evidences of forest-covered land getting drowned. Even today, trunks of those trees can be found at some depth.

Do you know ?

The Kachchh earthquake of June 16, 1819 submerged the coastal areas. This inflicted great damage to ships and country –made boats of the fishermen. The fort of Sindree on the sea coast was completely submerged except a single turret which remained above the water level. The land measuring around 1550 sq.km in area was raised upward because of this earthquake. This raised land is known as “Allah’s Bund”.

Slow Movements :

It is important to understand that in reality, these processes are very complex and interrelated. The Earth’s movements which are the result of internal forces are known as tectonic movements.

Based on the direction of these movements, they are classified as vertical and horizontal movements.

1) Vertical (Epeirogenic) Movements : Due to the forces in the interior of the earth and the travel of energy, these movements occur.

Slow movements keep on taking place either towards the centre of the earth or away from it towards the crust. Due to such movements, an extensive portion of the crust is either raised up or it subsides. When a portion of the crust is raised up above sea-level, it leads to the formation of continents. Hence such movements are also called continent-building movements. Such movement can also cause formation of extensive plateaus. Though these movement are slow they influence huge area. These movements are not related to development of tensions or pressure in the earth crust.

2) Horizontal (Orogenic) Movements : These movements work in horizontal direction. As per the direction, these movements produce compression or tension in the rock strata. These movements lead to either folds or cracks in the surface of the earth. These movement gives rise to mountains. These movements are also slow movements. But their speed is more than the continental-building movements. And their extent is also lesser. These movements produce either folds or faults. Consequently, either fold mountains or block mountains are formed. They are also called mountain-building processes. These forces are further divided into two types :

a) **Tensional Forces :** When the forces move away from each other and cause stress in the rock strata. See fig 1.2. This process creates ruptures, cracks, fractures and faults in the rock strata. This leads to crustal fracture

and the formation of faults. Rift valleys or block mountains are formed as a result of these forces.

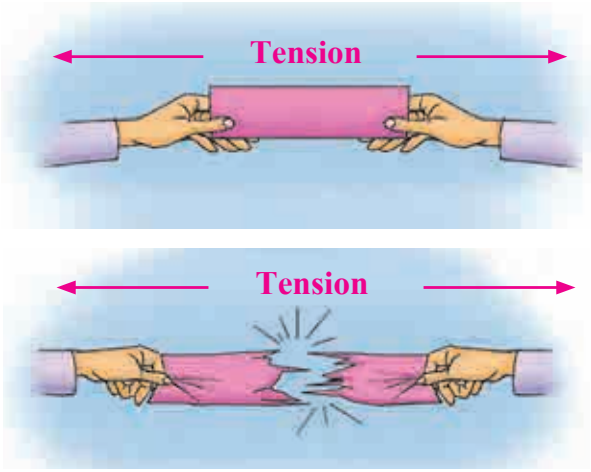


Fig. 1.2 : Tensional Forces

b) **Compressional Forces :** When the forces operate towards each other, they cause compression and hence are called as converging or compressional forces. See fig. 1.3. These movements cause various types of folding. These forces cause pressure on the layer of rocks. These lead to folding and faulting of the surface.

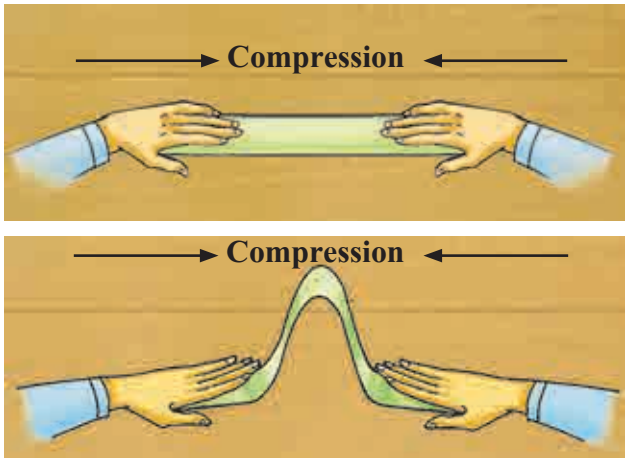


Fig. 1.3 : Compressional forces

Folding :

The nature of folding that occurs on the earth's surface depends on many factors. These include the nature of rocks, intensity and duration of force.

Soft and elastic rocks are affected more by these forces. When energy waves move through the layers of rocks on a large scale, folds are formed. Folding results into formation of fold mountains. For example, Himalayas, Alps, Rockies, Andes, etc. Compressional forces push two portions of crustal rocks together and tend to shorten and thicken the crust. The affected rocks react to compressional forces depending on the strength of the rocks and the speed of the forces.

Folding occurs when compressional forces are applied to rocks that are ductile or flexible. Rocks that lie deep within the crust and are therefore under high pressure are generally ductile and particularly susceptible to folding without breaking. As a result rocks deep within the crust typically fold rather than break. Folding is also likely to occur where compressional forces are applied slowly.

Think about it.

How will compressional forces affect brittle rocks?

Parts of fold : Folds develop in earth's crust. Both sides of a fold are called limbs. The axial plane divides a fold into two parts. The axis may be vertical, inclined or horizontal. A fold has two limbs.

As and when limbs slope downward with central portion getting raised up, it is called anticline. As against this, if limbs slope towards each other and the central part located at lower elevation, it is called synclines. See fig. 1.4.

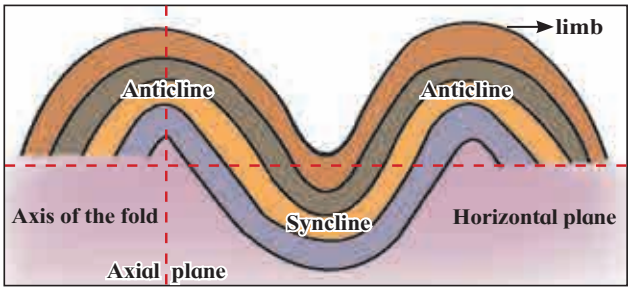


Fig. 1.4 : Parts of fold

Fold Mountains : Folding leads to development of fold mountains. e.g. the Himalayas, the Alps, etc.

They are classified as follows depending on their age. i.e.

1) Old fold mountains (over 200 million years of age, e.g. the Aravalis in India (Highest peak-1722m AMSL), the Urals in Russia and the Appalachians in USA.
2) Young fold mountains (10 to 25 million years of age, e.g. the Rockies and the Himalayas). The highest peak Mt. Everest 8848m AMSL.

Think about it.

'A mountain never remains a mountain'. Can you relate this idiom with the mountain building process?

Types of Folds :

Try this.

Observe the following diagrams in fig. 1.5. Try to understand the different types of fold shown in the diagram and match it with its characteristics. Write the name of the fold in the space given below.

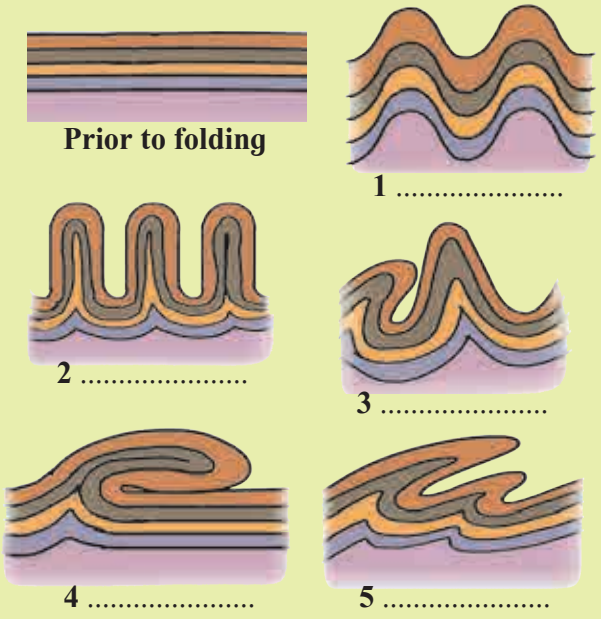


Fig. 1.5 : Types of folds

A) Symmetrical :

i) The axial plane is vertical.
ii) Limbs are inclined at same angle.

B) Asymmetrical :

i) The axial plane is inclined.
ii) The limbs are inclined at different angles.

C) Overturned :

i) One limb lies above the other limb.
ii) Limbs slope unequally in the same direction.

D) Recumbent :

i) Axial plane is almost horizontal.
ii) One limb lies over the other in horizontal direction.

E) Isoclinal :

i) The limbs slope in the same direction with same amount.
ii) The axial plane may be vertical, inclined or horizontal.
iii) Slope of some portion of limbs is near vertical.

Faulting :

In the earth's crust, the forces operating in opposite direction lead to tension. As a result, rocks develop cracks or fissures. In the regions where cracks developed rocks get displaced such displacement can occur in upward, downward or horizontal direction. Faulting can be classified according to displacement in rocks. Rock layers that are near the Earth's surface and not under high confining pressures are too rigid to bend into folds. If the tectonic force is large enough, these rocks will break rather than bend. Such breaks may also be called fractures, ruptures or faults. Also the rock masses will move relative to each other along the fracture i.e. the zone where they break.

One part of the rock strata moves along the plane of fracture upwards or downward relative to the other parts. The plane of fracture is called fault. Faulting results in the formation of block mountains and rift valleys.

Types of faults :

Try this.

Observe the diagrams in fig. 1.6 and read the explanation regarding the characteristics of various faults given below. Identify the faults and match each of them with their characteristics.

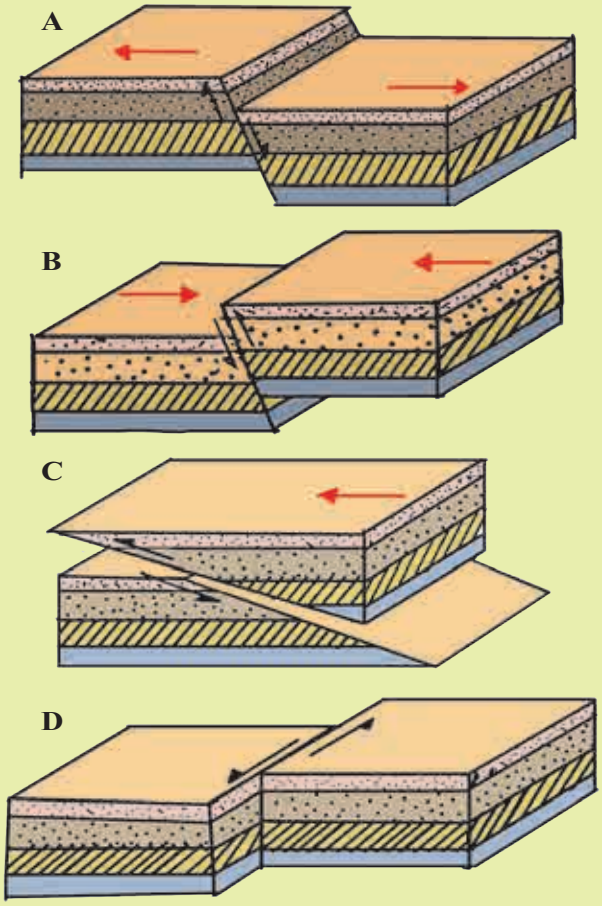


Fig. 1.6 : Types of faults

A) Normal fault : It results when a portion of land slides down along the fault plane and when the exposed portion of the plane faces the sky.

B) Reverse fault : It results when a portion of the land is thrown upward relative to other side of the land. In such situation, the fault plane faces the ground.

C) Tear fault : At times, the rock strata on either sides of the fault plane do not have vertical displacement. Instead movement occurs along the plane in horizontal direction.

D) Thrust fault : When the portion of the land on one side of the fault plane gets detached and moves over land on the other side. The angle of fault plane is generally low-less than 45°.

Block Mountain : Earth movements generate tensional forces that tend to pull the crust apart and faults are developed. If the block enclosed by the faults rises above or the land on either side subsides, the upstanding portion becomes the horst or block mountain. The faulted edges are very steep and the top portion is almost leveled. Generally the block mountain does not have a peak but a flat top. See fig 1.7. For example, the Vosges in France, the Black Forest Mountain in Germany, the Satpuras in Maharashtra and the Meghalaya Plateau in India are examples of block mountains.

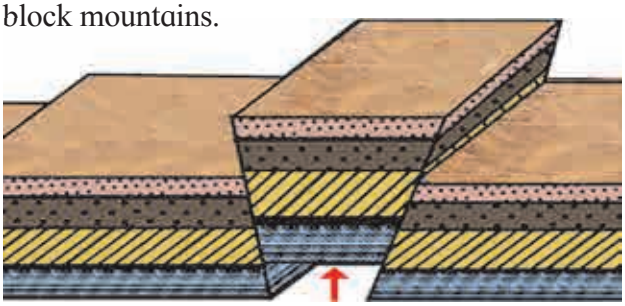


Fig. 1.7 : Block mountain

Rift Valley : The tension may also cause subsidence in the central portion of the crust between two adjacent faults, forming graben or rift valleys. These have steep walls. Their walls are formed by fault planes. In most of the cases these walls of the rift valley face the sky. The African Rift Valley is an example of this type of landform. In India, valleys of the Narmada and the Tapi are well known examples of rift valley. See fig. 1.8.

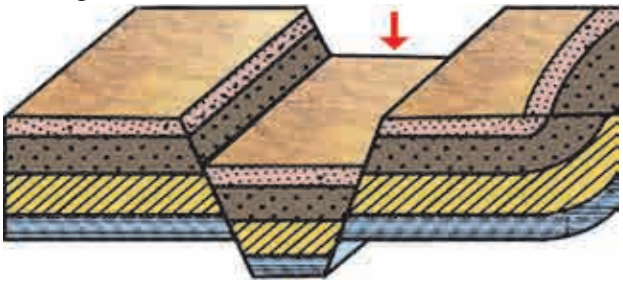


Fig. 1.8 : Rift valley

Think about it.

1) When can faults form in fold mountains?
2) Can folds form in block mountains? Find the reasons and discuss.

Sudden Movements :

Beside the folding and faulting movements responsible for the formation of fold mountains and block mountain respectively, there are other movements in the earth's crust. Due to some internal forces at times, movements occur suddenly. Earthquake and volcanic eruptions are the types of these movements which are episodic in nature.

Let's recall.

On 19th August, 2018, around 300 people died in Indonesia. Many buildings collapsed. Many roads broke apart. A tsunami was generated.

a) What was the cause behind these events?
b) What actually happened during this natural event?
c) Name the energy waves involved in this natural event.
d) Observe the diagram in figure 1.9 and label the boxes.

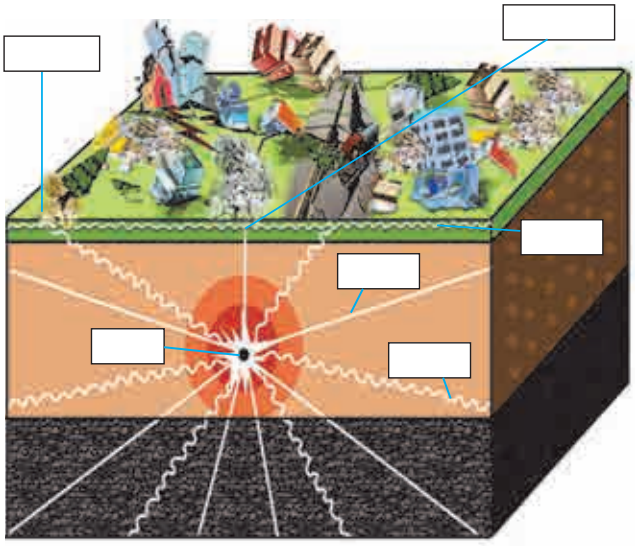


Fig. 1.9 : Earthquake

Earthquake :

Earthquake refers to shaking of the ground. Movements occurring in the crust of the earth produce a lot of stress in the rock strata. When this stress accumulates beyond a limit, it tends to get released in the crust. Release of stress causes release of energy. Here, release of energy produces energy waves. This makes the earth's crust to shake. This is called an earthquake.

The point where the accumulated stress gets released within the earth crust is called seismic focus. A point directly above it, on the surface, is called an epicentre. The intensity of the shock is maximum at the epicentre and decreases with increasing distance from the epicentre in all directions. The earthquake waves are recorded by an instrument called seismograph.

Think about it.

Look at fig. 1.10. During an earthquake, do you think the seismic waves reach entire portion of the earth? Is there any region on the Earth's surface where a given earthquake will not be reported?

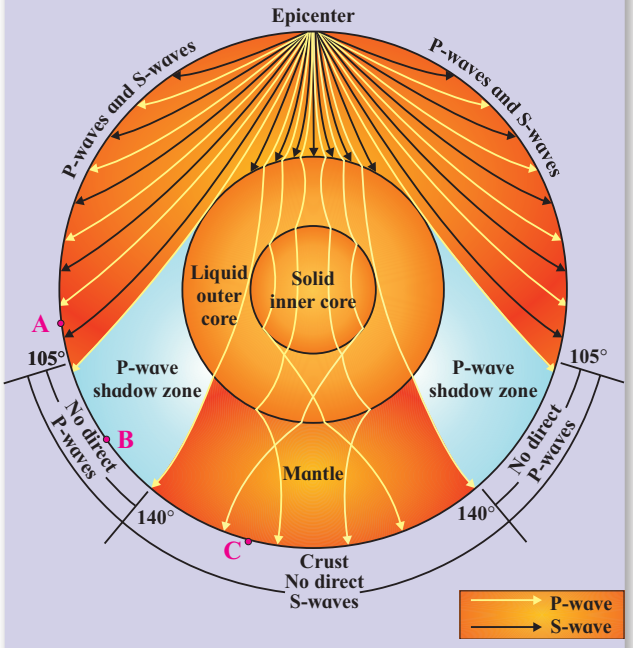


Fig. 1.10 : Shadow zone of an earthquake

Shadow zone :

The waves which are caused by the earthquake are called seismic waves. There are three types of waves : P-waves, S-waves and longitudinal waves. P-waves pass through all mediums while S-waves pass only through solid medium. Even though P-waves pass through all mediums, they experience refraction as they pass on one medium to another. Earthquake waves get recorded in seismographs located at far off locations. However, there exist some specific areas where the waves of that earthquake are not reported. Such a zone is called the 'shadow zone'. The study of different events reveals that for each earthquake, there exists an altogether different shadow zone. Figure 1.10 shows the shadow zones of P and S-waves. Generally, seismographs located at any distance within 105° from the epicentre, record the arrival of both P-waves and S-waves. However, the seismographs located beyond 140° from the epicentre; record the arrival of P-waves, but not that of S-waves. Thus, a zone between 105° and 140° from the epicentre is identified as the shadow zone for both the types of waves. The entire zone beyond 105° does not receive S-waves. The shadow zone of S-waves is much larger than that of the P-waves. The shadow zone of P-waves appears as a band around the earth between 105° and 140° away from the epicentre. The shadow zone of S-waves is larger in extent. You can draw the shadow zone for any earthquake provided you know the location of the epicentre.

Think about it.

Why has a shadow zone for L-waves not been shown in fig. 1.10?

Can you tell ?

In fig. 1.10 A, B, C are three points on the earth's surface. Analyse their locations with respect to epicentre and shadow zones.

Do you know ?

Isoseismal line is an imaginary line, drawn on the map, connecting the places of uniform intensity of earthquake.

Always remember

While the Mercalli scale describes the intensity of an earthquake based on its observed effects, the Richter scale describes the earthquake's magnitude by measuring the seismic waves that are caused by the earthquake. The two scales have different applications and measurement techniques. The energy released in an earthquake of a magnitude 5 is 32 times more than that of magnitude 4.

Scale	Mercalli Scale	Richter Scale
What does it measure?	The intensity of earthquake	The energy released during an earthquake
Measuring Tool	Observation	Seismograph
Quanti-fication	Quantified from observation of the effects on earth's surface, humans, objects and man-made structures	Logarithmic scale obtained by calculating logarithm of the amplitude of waves.
Unit	I (not felt) to XII (total destruction)	From < 2.0 to 10.0+ (never recorded). 3.0 earthquake releases 32 times more energy than a 2.0 earthquake.

Give it a try.

How to locate epicentre of a given earthquake?

Take the given hypothetical data in the table. The data shows the time of arrival of P-waves and S-waves at 3 seismograph stations. Assume the scale of the map as 1 cm : 18 km. See fig. 1.11.

Recording Station	P-wave arrival time (IST)	S-wave arrival time
Jalana	11: 06: 06	11: 06: 19
Washim	11: 06: 46	11: 07: 03
Aurangabad	11: 07: 06	11: 07: 24

Procedure :

1) Compute the time difference between the arrival of P-waves and S-waves for each station; this is called time lag. (It shows the distance of the seismograph from the focus. *Thumb rule: For every second of time lag, the earthquake is approximately 8 km away.*)
2) Using the rule above, convert the time lag into distance (seconds of time lag × 8) for each station.
3) Convert this distance into centimetres as per the scale of the map.
4) On a map, locate the seismograph stations.
5) Draw circles, taking the seismograph stations as the centre, with the radius equal to the distance you have calculated in the previous step.
6) These arcs of circles will intersect one another at a point. This point is the location of the epicentre.

In normal practice, an epicentre is located using computer models. The procedure outlined here is a much simplified version of what is normally done, although the principle is the same.

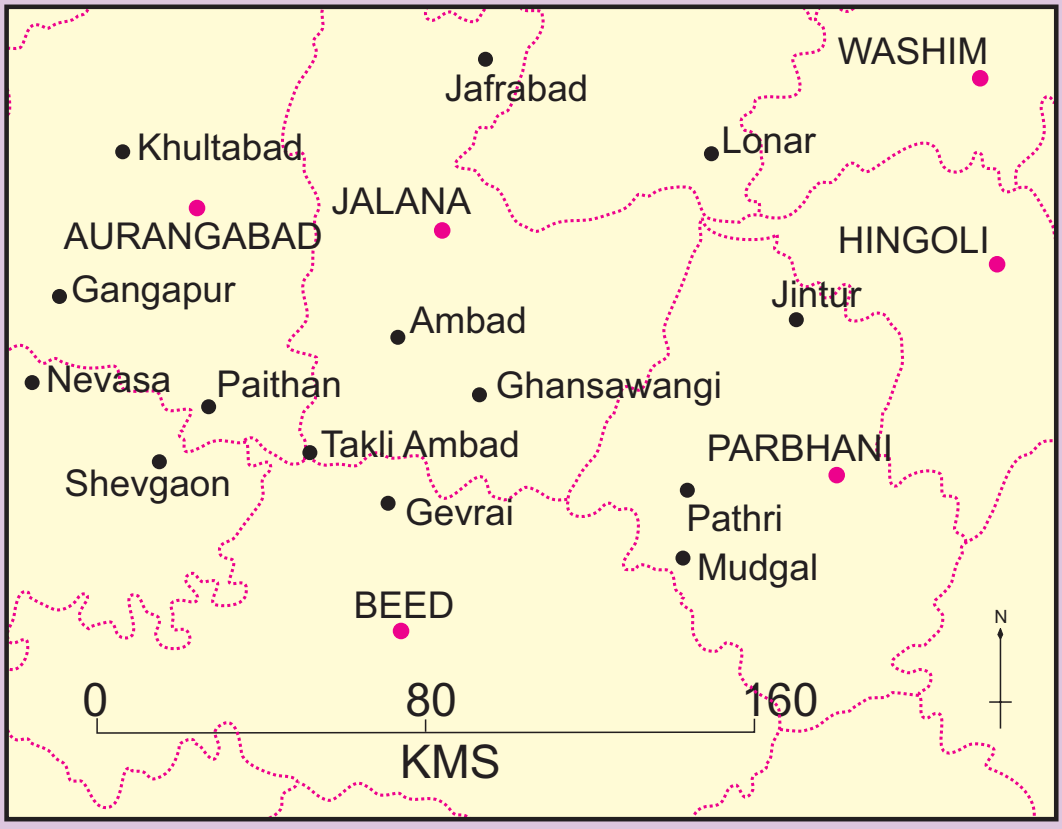


Fig. 1.11

Causes of Earthquakes : Now you know that earthquakes are caused mainly due to the release of stress within the crust. Following are some of the causes of an earthquake.

1) **Volcanicity :** Some, but not all, earthquakes are associated with volcanic eruptions. Such earthquakes are generally shallow and their effect is seen mostly in the areas close to eruption site. e.g. A volcanic earthquake in the Cascades near Mount St. Helens was of magnitude 5.5 in 1981.

2) **Tectonic Movements :** The earth's crust consists of several large and small unstable tectonic plates. They float on denser portion of the upper mantle zone. Due to their movements, the earthquake generally occurs along their margins (divergent and convergent). Refer to the map in fig. 1.21. The earthquakes which generally occur in Indonesia, California (North America), Chile (South America), Uttar Kashi and Assam in India are examples of such earthquakes.

3) **Anthropogenic causes :** In recent years, earthquakes have occurred due to an atomic explosion, large construction activity, drilling, blasting, and large scale mining in different parts of the world may also lead to earthquakes. However, their effects are highly localized.

Earthquake Zones in India :

On the basis of the intensity of damage risk, India is classified into five risk zones. Use the given weblink http://www.bmtpc.org/DataFiles/CMS/file/map%20of%20india/eq-india.pdf and complete the table accordingly.

Seismic Zones in India

Zone	Degree of Risk	States/UTs
I	Least	
II	Low	
III	Moderate	
IV	High	
V	Very High	

Volcanoes :

Volcano is an opening in the earth's surface through which gases, molten lava and solid material are ejected from the upper mantle portion on to the surface of the earth.

On the basis of origin of eruption, volcanoes can be classified into two types. i.e. 1) Eruption through cones, 2) Eruption through fissures. (fig 1.12 and 1.13)

Fig. 1.12 : Central or Conical Volcano

Fig. 1.13 : Fissure type volcano

Volcanoes may also be classified on the basis of periodicity and continuance of the eruption activity, like active volcanoes, dormant volcanoes and extinct or dead volcanoes.

Find out !

Find out examples of active, dormant and extinct volcanoes.

Volcanic Materials :

Read the following passage about the Krakatoa volcanic eruption and answer the following questions.

- Make a list of materials that came out during eruption.
- Classify them into liquid, solid and gaseous forms.

There is an island known as Krakatoa between the islands of Java and Sumatra in Indonesia. There were frequent volcanic eruptions here. From May 1883, massive explosions began. The eruption that took place at about 10 in the morning on 28 August 1883 was the largest ever recorded explosion. As a result of this explosion, the entire island disappeared. During this eruption, rock particles and dust thrown up in the atmosphere was about 25 km^3. The column of this dust-ash rose as high as 80 km. The discharge of Krakatoa threw into the air nearly 21 km^3 of rock fragments, and large quantities of ash fell over an area of some 800,000 km^2. Near the volcano, masses of floating pumice, were so thick that ships had to halt. The surrounding region was plunged into darkness for two and a half days because of ash in the air. For some years after this, cloud kept moving round the earth. About 36,000 people died in these eruptions and the tsunami waves created by it.

In 1927, volcanic eruptions began at the same place and a new island rose in place of the Krakatoa island that had vanished. It was named 'Anak Krakatoa' or 'Child Krakatoa'. The volcano here constantly emits ash and steam. This new island has now become a laboratory for geologists and biologists.

There are mainly three types of material which come out in volcanic eruptions, namely, liquid, solid and gaseous forms.

Geographical explanation

1) **Liquid material :** It is the molten rock material. When the molten rock material is below the earth surface it is called 'magma'. When it appears on the surface it is called 'lava'. On the basis of percentage of silica it is classified into two types

a) Acidic Lava : It contains higher percentage of silica. It has got high melting point. It is thick, fluid and moves slowly.

b) Basic Lava : It contains less percentage of silica. It has low melting point. Its more fluid and can flow over longer distances.

2) **Solid material :** It consists of dust particles and rock fragments. When the material is very fine it is called volcanic dust. The small sized solid particles are called ash. The solid angular fragments are known as breccias. Sometime, the lava material thrown into the air solidifies into small fragments before falling on the earth surface; it is called volcanic bombs.

3) **Gaseous Material :** At the time of volcanic eruption, a dark cloud of smoke can be seen over the crater. On the basis of shape, cloud is called cauliflower cloud. Various inflammable gases are found in these clouds. These gases produce flames.

Volcanic Landforms :

A number of landforms are formed due to cooling and solidification of magma. Some important landforms are given below.

1) **Lava Domes :** Domes are developed when magma comes out and solidifies around its mouth. The shape of the dome depends upon fluidity of lava. High dome with steep slopes are developed by acidic lava. Due to basic lava, broad-based low domes are developed. See fig. 1.14.

Fig. 1.14 : Lava Domes

2) **Lava Plateaus :** Due to spread of lava in huge quantity from fissure volcano, it covers large areas and plateaus are formed. The Deccan Trap in India has developed from volcanic eruptions millions of years ago. See fig. 1.15.

Fig. 1.15 : Lava Plateaus

3) **Caldera :** At times, the eruption of a volcano brings about large quantity of material and relieves lot of pressure. After the eruption, a large and deep depression remains in that area. This large depression is called caldera. These can be around 10 km wide and hundreds of metres deep. They may later turn into lakes. Smaller calderas are known as craters. See fig. 1.16.

Fig. 1.16 : Caldera

4) **Crater lake :** When the funnel shaped crater of an extinct volcano is filled with rain water, its forms a crater lake. See fig. 1.17.

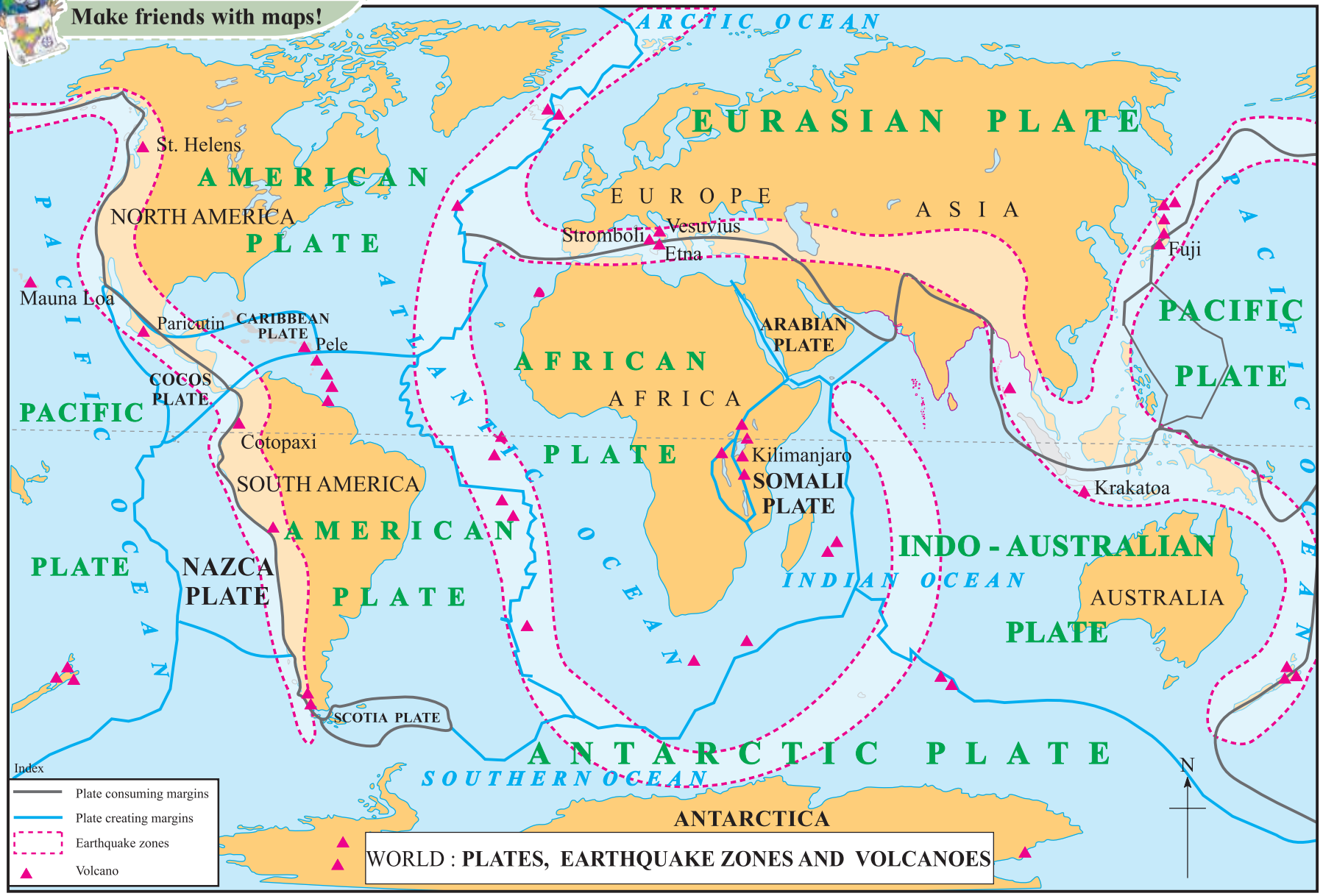
Fig. 1.17 : Crater lake

5) **Volcanic plug :** It is formed, when the lava solidifies in the volcanic neck.

Fig. 1.18 : Volcanic plug

6) **Cinder Cone :** Solid material is ejected in large quantity. This material consists of ash, cinder and breccias. Cinders are half burnt pieces of solid material. The solid material is deposited around the mouth until a conical hill with steep slopes is formed. For example cone of Mt. Nuovo in Italy. See fig. 1.19.

Fig. 1.19 : Cinder Cone



WORLD : **PLATES, EARTHQUAKE ZONES AND VOLCANOES**

Fig. 1.20

7) **Composite Cone :** Composite cones are built up of alternate layers of lava and cinder. This cone is composed of two materials and therefore it is called a composite cone. It is symmetrical in shape. e.g. Mt. St. Helens, USA. See fig. 1.21.

Fig. 1.21 : Composite Cone

Distribution of Earthquakes and Volcanoes :

There are three major belts or zones of earthquake and volcanoes on the earth. Look at the map given in fig. 1.20.

1) **Circum-Pacific Belt :** This belt is also called as "Ring of Fire". It includes the volcanoes of Eastern and Western coastal areas of the Pacific Ocean. Most of high volcanic cones and volcanic mountains are seen in this belt. Cotopaxi is the highest volcanic mountain of world found in this belt. Fujiyama (Japan), Mt. St. Helens (Washington, USA), Pinatubo and Mayon (Philippines) are other significant volcanoes.

2) **Mid-Atlantic Belt :** This belt covers the volcanoes mainly along the Mid-Atlantic ridge. The most active volcanic area is Iceland which is found on Mid-Atlantic ridge.

3) **Mid-continental Belt :** This belt includes the volcanoes of Alpine mountain chains, the Mediterranean Sea and volcanoes of fault zone of eastern Africa. The famous volcanoes are Stromboli and Etna.

Exercise

Q. 1) Complete the chain :

A	B	C
1) Widespread volcanic eruption	1) Zone V	1) I to XII
2) Andaman and Nicobar Islands	2) Fissure eruption	2) Block Mountain
3) Mercalli scale	3) Intensity	3) Very high seismic vulnerability
4) Slow movements	4) Faulting	4) Solid
5) Phillippines	5) Volcanic bombs	5) Deccan Trap
6) Volcanic material	6) Circum Pacific belt	6) Mayon

Q. 2) Identify the correct correlation :

A : Assertion; R : Reasoning

1) A : Faulting leads to development of fold mountains.

R : Faulting occurs when tensional forces move away from each other.

1) Only A is correct

2) Only R is correct

3) Both A and R are correct and R is the correct explanation of A.

4) Both A and R are correct but R is not the correct explanation of A.

2) A : Intensity of an earthquake is a measurement of the energy released during an earthquake.

R : Mercallis scale is used to measure intensity of an earthquake.

1) Only A is correct
2) Only R is correct
3) Both A and R are correct and R is the correct explanation of A.
4) Both A and R are correct but R is not the correct explanation of A.

3) A : South-East Asia, Japan and islands in the Pacific Ocean are most vulnerable to earthquakes and volcanic eruption.

R : They are located in 'Ring of Fire'.

1) Only A is correct
2) Only R is correct
3) Both A and R are correct and R is the correct explanation of A.
4) Both A and R are correct but R is not the correct explanation of A.

Q. 3) Identify the correct group :

A) 1) Symmetrical fold
2) Isoclinal fold
3) Overturned fold
4) Recumbent fault

B) 1) Black Forest
2) Vosges
3) Himalayas
4) Satpuras

C) 1) Narmada Valley
2) African Valley
3) Tapi Valley
4) Rhine Valley

D) 1) Caldera
2) Crater lake
3) Cinder Cone
4) Lava plateau

Q. 4) Give geographical reasons :

1) Extinct conical volcanoes often form crater lakes.
2) People living in the Himalayas are more vulnerable to earthquakes.
3) L-waves do not have a shadow zone.
4) Soft rocks form folds while hard rocks form faults.
5) Folds depend on the strength of rocks and intensity of forces.

Q. 5) Answer in detail :

1) Explain different types of faults.
2) Explain with examples, different types of landforms produced by volcanic eruption.
3) Explain the concept of shadow zone.
4) Write a note on volcanic materials.

Q. 6) Differentiate between :

1) Folding and faulting
2) Normal fault and Reverse fault
3) Syncline and Anticline
4) Asymmetrical fold and Symmetrical fold
5) Mercalli scale and Richter scale
6) Slow movements and sudden movements

Q. 7) Draw diagrams for :

1) Types of folds
2) Types of faults
3) Shadow zone
4) Volcanic landforms

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