

CHAPTER

8

Earthquakes

Syllabus

Earthquakes: Meaning, causes and measurement.

Effects: destructive and constructive.

Earthquake zones of the World.

An **earthquake** is defined as a tremor below the surface of the earth which causes shaking of the crust. These devastating tremors are caused by the stresses that break the earth's crust.

Causes of Earthquakes

Earthquakes are caused by the strain in the earth's crust which in turn is a result of a number of factors. When the earth's crust is unable to accommodate itself to the strain, it results in a sudden release of tremendous energy in the form of a sudden violent shock.

A series of shocks that result from sudden earth movement, e.g. along a fault, are known as earthquake (seismic) waves. The waves spread out from the seismic focus of the earthquake and can cause widespread destruction. In areas of the world that lie along the edges of lithospheric

plates, for example, down the western edge of the Pacific Ocean, earthquakes are common. The severity of earthquakes is measured on the Richter scale. The main factors that cause earthquakes are the following:

(i) **Volcanoes:** Volcanic eruptions are one of the main causes of earthquakes. During the volcanic eruptions, hot gases are pushed upward and they push violently the earth's crust surface upward causing earthquakes. Volcanic activities and seismic occurrences (earthquakes) are interrelated: an earthquake follows a volcanic eruption and a volcanic eruption follows an earthquake. The violent eruption of Krakatoa volcano between the islands of Sumatra and Java caused severe earthquake around a vast

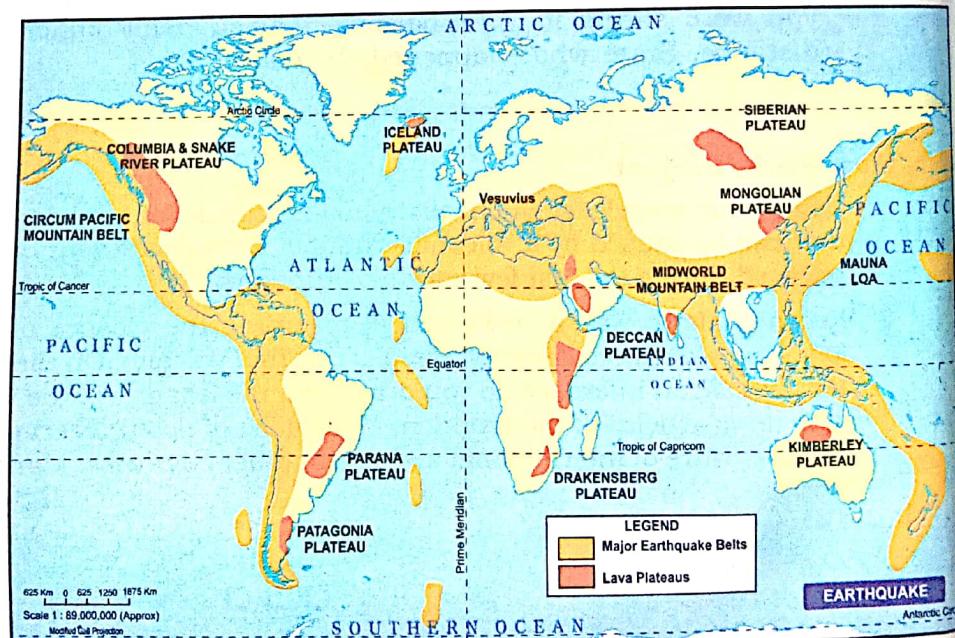


Fig. 8.1. Distribution of Earthquake belts

region. The earthquake generated Tsunami (tidal waves) which killed about 30,000 people in Java and Sumatra.

(ii) **Plate Tectonics:** According to the plate tectonic theory, the crust of the earth is made of a series of moveable plates. These plates move and slide over each other. Most earthquakes occur on account of plate movements. When two plates slip past each other or collide against each other, their edges produce faults along the lines of weakness.

The tectonic earthquakes are most frequent. These earthquakes are immensely powerful. They occur in high risk regions of the 'Pacific Ring' of South East Asia (Philippines and Indonesia) and northern India, along plate boundaries.

In India, a severe earthquake occurred at Bhuj in Gujarat in 2001 due to lowering of the Indian plate below the Asiatic plate.

(iii) **Folding and Faulting:** Internal horizontal and vertical movements due to compressional and tensional forces cause folding and faulting in the earth's crust. This causes displacement of rocks in the crust. Such an imbalance causes earthquakes. For example, in 1906 San Andreas Fault of California (USA) gave rise to a major earthquake that measured 8.3 on the Richter scale and broke the earth's surface along a 402 km length.

(iv) **Man-made Causes:** Human activity like construction of huge dams, nuclear explosions, blasting of rocks, mining, etc., near fault zones are responsible for earthquakes. Koyna earthquake in Maharashtra was caused by construction of

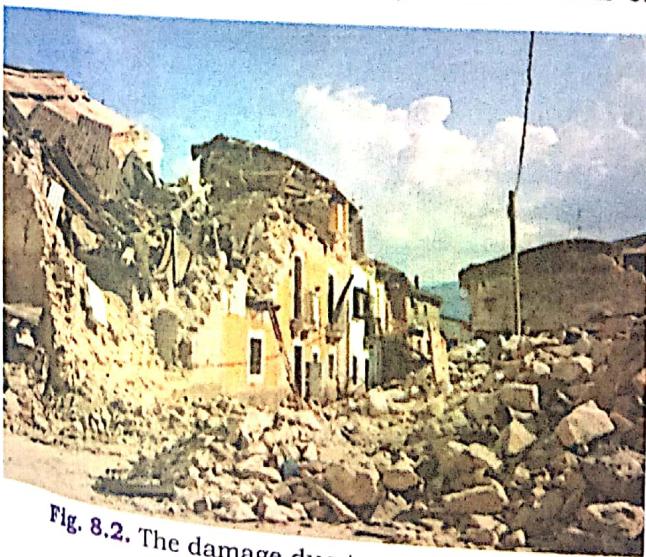


Fig. 8.2. The damage due to an earthquake

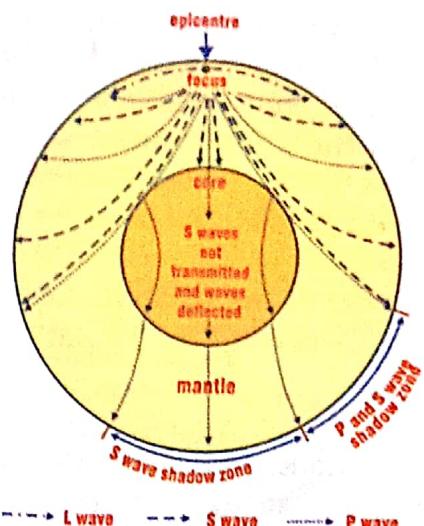


Fig. 8.3. Earthquake waves

the Koyna dam in a seismically active region. Chemical wastes dumped into the ground and underground explosions in the USA caused several earthquakes in Colorado in the 1960s.

Anatomy of an Earthquake

The tension caused by the movement of the earth's plates builds up until it is released in the form of powerful vibrations. These vibrations travel in three types of waves: P-Primary waves, S-Secondary (or Shear waves) and L-Long waves (or Surface waves).

- (i) P (primary or push) waves are the first earthquake waves to be recorded on a seismogram of an earthquake. They are compressional, i.e., the particles vibrate in the direction of movement of the wave, similar to a sound wave. They can pass through solids, liquids and gases.
- (ii) S (secondary or shear) waves are recorded on a seismogram after the P waves. They are distortional waves in which the particles vibrate at right angles to the direction of movement of the wave. S-waves travel through the earth's interior but cannot be transmitted by liquids.
- (iii) L (surface or long) waves travel along the surface of the earth and are recorded after the P and S waves. Two types of L waves are identified: *Love waves* and *Rayleigh waves*.

The P-waves and S-waves travel through the interior of the earth. The surface waves (or

L-waves) are the last to arrive. The S-Waves are slower and do not pass through liquids. It is these waves that make the inhabitants of the earth feel the ground motion. *The point of origin of these waves (called Seismic waves) is called Seismic focus. The point on the earth's surface directly above the seismic focus is called epicentre.* Most of the earthquakes have their seismic focus between 8 to 35 km in depth.

Measurements

Seismograph, the Richter Scale and the Mercalli scale are used for measuring the direction and intensity of earthquakes.

Seismograph

The direction of movement of waves and their passage at a particular point is recorded by an instrument called *Seismograph*. It has a pen attached to it. The pen vibrates with the earthquake waves, recording their movements on a travelling strip of paper. It also calculates the difference in the arrival of P and S waves. This interval is then used to calculate the distance between the recording station and the epicentre.

Richter Scale and the Mercalli Scale

Both these instruments measure the intensity (or the amount of energy released during an earthquake). The Richter scale measures the power of an earthquake on a scale of 1 to 9. It measures the absolute intensity with mathematical precision. Fig. 8.4 approximately shows the effect of earthquakes according to the Richter Scale reading.

The Mercalli scale grades the earthquakes on the basis of observed effects on a 12-point scale. The Richter scale is most commonly used. Each point upward from 1 represents 10-fold increase in the amplitude of shock waves. Thus an earthquake wave of magnitude 6 will be 10 times stronger than magnitude 5.

The Assam earthquake in India of 1897 was of 8.7 magnitude. The Gujarat earthquake in 2001 had the magnitude of only 7.7 on the Richter Scale yet it caused the greatest damage.

In Nepal, an earthquake measuring 7.8 on the Richter scale occurred on April 25, 2015,

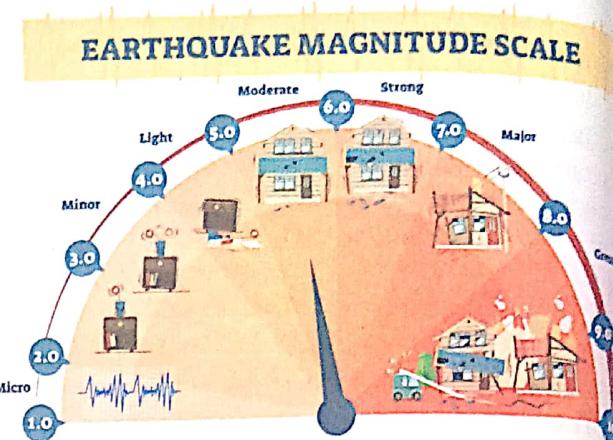


Fig. 8.4. Scale showing damage due to Earthquake

which killed over 8,000 people and injured more than 21,000. It made many people homeless with entire villages flattened across many districts of Nepal. It also destroyed centuries old buildings including UNESCO World Heritage sites in the Kathmandu Valley. Continue aftershocks occurred throughout the Nepal at intervals of 15 to 20 minutes.

A major aftershock occurred on May 12, 2015 with a magnitude of 7.3 on the Richter scale, which killed more than 200 people and injured 2500 people.

Effects of Earthquakes

In geological terminology earthquakes are part of endogenic forces and are regarded as constructive movements of the earth's crust but from human point of view earthquakes are regarded as destructive causing loss to property and life.

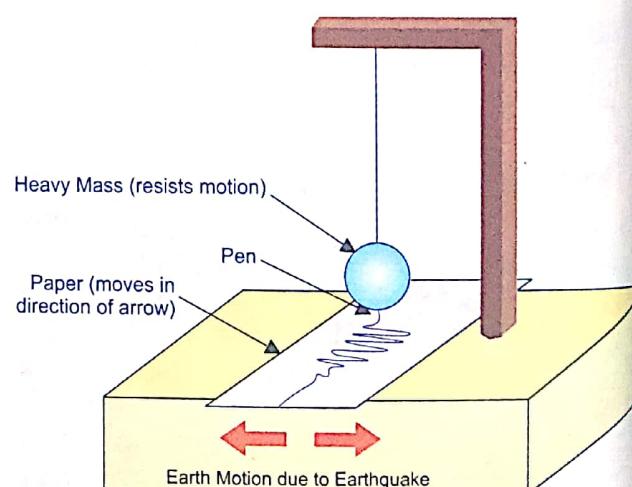


Fig. 8.5. Seismograph

(i) Constructive Effects

1. **Energy release:** Earthquakes help the earth release its stored up energy. The majority of the earthquakes occur around the plate margins. This energy release helps to keep the earth in good shape.
2. **Landforms:** On account of both vertical and lateral displacement of the earth's crust, earthquakes may raise or lower parts of earth especially near the seashore. Sagami Bay of Japan was uplifted 200 m in 1923. Landslides triggered by earthquakes cause formation of lakes as has happened at many places in the Himalayan region.

(ii) Destructive Effects

1. **Collapse of structures:** Human beings have settlements in active earthquake zones. Often these houses and other structures collapse causing great loss of property. For example, the destruction caused by a tsunami.
2. **Submergence:** The forces of uplift and subsidence also cause submergence of coastal parts. For example: Dwarka in Gujarat which now lies submerged under the sea.
3. **Course of Rivers:** Earthquakes have changed the course of rivers in the past. They have thus rendered many areas unsuitable for irrigation and agriculture.
4. **Danger to human life:** Many severe earthquakes in the past have killed hundreds to lakhs of people. They died on account of house collapse or under the weight of falling trees, poles, bridges or other structures. Landslides and floods caused by earthquakes also kill people and animals.
5. **Landslides:** The shockwaves during an earthquake destabilise the loose rocks which lead to landslides. This damages the buildings and disturbs the transport system. The earthquakes in the Himalayas, Alps and Andes also cause landslides.
6. **Fires:** During the earthquakes, fires break out due inflammable material thrown out, broken gas pipes and bursting of gas cylinders. Besides damaged oil refineries

and live electric wires catch fire and damage life and property in the townships and factory complexes.

7. **Tsunami:** A tsunami is a large destructive ocean wave that can be generated by any disturbance that rapidly displaces a large mass of water, such as an earthquake, volcanic eruption, landslide or meteorite impact. However, the most common cause is an undersea earthquake. The name 'tsunami' is from the Japanese words: 'Tsu' and 'nami' meaning 'harbour' and 'wave' respectively. So tsunamis are harbour waves.

Tsunamis occur most frequently in the Pacific Ocean, but are a global phenomenon; they are possible wherever large bodies of water are found, including inland lakes, where they can be caused by landslides.

Major Earthquakes of the World

	Location	Year	Estimated deaths
1.	Shansi, China	1556	830,000
2.	Kolkata, India	1737	300,000
3.	Tangshan, China	1976	255,000
4.	Gansu, China	1920	200,000
5.	Near Xining China	1927	200,000
6.	Kwanto, Japan	1923	144,000
7.	N.E. Iran (7.1)	1997	2,400
8.	Takhar (6.1) Afghanistan	1998	4,200
9.	Rostaq Afghanistan (7.1)	1998	5,000
10.	Izmit Turkey (7.4)	1999	15,000
11.	Tapei, Taiwan (7.6)	1999	1,700
12.	Gujarat, India (7.7)	2001	18,300
13.	Off West Coast of Northern Sumatra (9.1)	2004	2,27,898
14.	Pakistan (7.6)	2005	80361
15.	China (7.9)	2008	87587
16.	Near the East Coast of Honshu, Japan (9.0)	2011	20896
17.	Nepal (7.8)	2015	8000
18.	Indonesia (Sulawesi Province) (7.5)	2018	2000
19.	Turkey (7.8)	2023	40000



Fig. 8.6. Landslides caused by Earthquake.

The 2004 Indian Ocean earthquake, triggered a series of lethal tsunamis on December 26, 2004 that killed approximately 2,75,000 people (more than 168,000 in Indonesia alone), making it the deadliest tsunami in the recorded history.

8. Flash Floods: Strong shock waves damage dams and embankments and the water stored there spreads speedily causing flash floods. Besides, debris produced during the earthquake blocks the flow of the river. The river flow gets diverted from its original course. This diversion causes flash floods and cause damage to life and property.

Distribution of Earthquakes

Most earthquakes originate from plate boundaries. In regions where an ocean plate and land plate converge, submarine ridges are formed. The underlying rocks are unstable and subjected to movement. Any such movement triggers earthquakes in the continental areas.

A tsunami struck Java and Sumatra in Indonesia on December 22, 2018, resulting in more than 300 deaths. The tsunami was likely caused by undersea landslides due to the ongoing eruption of Anak Krakatau volcano located in the Sunda Strait. Indonesia is an archipelago that is located on the *Pacific Ring of Fire* and includes thousands of volcanic islands, which have been created over time as plates shifted and molten magma exerted pressure.

These ridges join with the fold mountain ranges on the continents. The main earthquake belts of the world are:

- (i) **The Circum Pacific Mountain Belt:** This belt has 70% of all earthquakes. A part of the San Andreas Fault in the USA lies in this belt. This fault-zone makes California in USA highly prone to earthquakes. The area of Japan, the Philippines and Indonesia all form parts of this belt and are prone to severe earthquakes.
- (ii) **The Mid-world Mountain Belt:** This belt stretches from Eastern Europe covering the Alpine-Himalayan ranges in Europe and Asia. About 20% of all earthquakes occur in this zone.
- (iii) **The Mid-Atlantic Ridge:** This belt comprises areas along the mid-ocean ridges as well as many islands near the ridges of the Atlantic Ocean and the remaining 10% of earthquakes occur in this belt. In this ridge two tectonic plates move in opposite direction. Some moderate earthquakes are recorded along the ridge. The Rift Valley of East Africa is considered as an extension of the belt.

Predicting Earthquakes

Earthquake prediction in the past was left to astrologers and mystics. Today it is a respectable scientific pursuit. The Russians were the first to discover P and S seismic waves in 1960s on the basis of which predictions were made. These waves still are the only means available to seismologists to predict earthquakes.



Fig. 8.7. Tsunami

The theory of Plate Tectonics offers another means of prediction on scientific lines. Japanese use the methods of measuring changes in sea level and variations in Earth's magnetic field

to predict earthquakes. However, no method is still foolproof as has been proved by recent earthquakes in Japan, India and the USA.

Terms to Remember

Seismic	: Pertaining to earthquakes.
Tsunamis	: Ripples and storms in oceans generated by oceanic earthquakes.
Seismic Focus	: The point of origin of seismic waves.
Epicentre	: The point on the earth's surface directly above the seismic focus.
Fold	: A bend in layered rocks in the crust. Folds are most commonly found in sedimentary rocks; but they can also occur in igneous and metamorphic rocks.
Fault	: A fracture in the earth's crust along which the blocks of crust on either side have moved relative to one another.
Fault Plane	: The planar (flat) surface along which there is a slip during an earthquake. The more or less planar surface of a fault.

EXERCISES

I. Choose the correct option:

1. A tremor below the surface of the earth which causes shaking of the crust:
(a) Earthquake waves (b) Earthquake (c) Seismic waves (d) None of the above
2. A series of shocks that result from sudden earth movement:
(a) Earthquake (b) Volcanoes (c) Earthquake waves (d) Plate tectonics
3. Which amongst the following is NOT a factor that causes an earthquake?
(a) Folding and faulting (b) Volcanoes
(c) Lava (d) Plate tectonics
4. Which waves are recorded on a seismograph after the P waves?
(a) Primary waves (b) Push waves (c) Shear waves (d) Surface waves
5. Which of the following measures the power of an earthquake on a scale of 1 to 9?
(a) Seismograph (b) Richter scale (c) Mercalli scale (d) Thermometer
6. The point on the earth's surface directly above the seismic focus is called:
(a) Epicentre (b) Seismic focus (c) Seismograph (d) Mercalli
7. The instrument that grades the earthquakes on the basis of observed effects on a 12-point scale.
(a) Thermometer (b) Seismograph (c) Richter scale (d) Mercalli scale
8. Which, amongst the following, is NOT a destructive effect of earthquakes?
(a) Submergence (b) Landslides (c) Energy release (d) Tsunami
9. A large destructive ocean wave that can be generated by any disturbance (earthquakes, volcanoes etc.) that rapidly displaces a large mass of water:
(a) Submergence (b) Tsunami (c) Landform (d) Volcano
10. Which of the following is not correct?
(a) Circum Pacific Mountain Belt : 70% of world earthquakes
(b) Mid Atlantic Ridge : 10% of world earthquakes

- (c) Mid-world Mountain Belt : 20% of world earthquakes
- (d) Pacific Ring of Fire : 15% of world earthquakes

II. Short Answer Questions

1. What is called an earthquake? Give one recent example of an earthquake.
2. State two natural causes of an earthquake.
3. Name two man-made causes of an earthquake. Give one example.
4. What are known as seismic focus and epicentre with respect to an earthquake?
5. What is known as Richter scale? State its uses.
6. How are earthquakes useful?
7. Give any two destructive effects of earthquakes.
8. What is a tsunami? Give one recent example of a place struck by a tsunami.
9. How do Japanese predict earthquakes?
10. Name the two belts where most of the earthquakes occur.

III. Structured Questions

1. (a) Describe how earthquakes are caused on the surface of the earth.
(b) What is the difference between seismic focus and epicentre?
(c) Give a geographical reason for each of the following:
 - (i) Most earthquakes occur on account of plate movements.
 - (ii) Primary waves are the first earthquake waves to be recorded on a seismogram.
 - (iii) Volcanic activity and earthquakes occur in the same belt.
(d) Explain the three types of earthquake waves.
2. (a) The destructive effects of an earthquake are far more than its constructive effects. Give reasons to support your answer.
(b) How is the intensity of an earthquake measured?
(c) Is it possible to predict an earthquake? Give reasons to support your answer.
(d) How are earthquakes distributed over the globe?

IV. Thinking Skills

1. 'Prevention is better than cure.' How does this statement apply to earthquakes? Give reasons to support your answer.
2. Imagine you were sitting in the balcony of a seaside resort, when you suddenly noticed waves rising high in the sky. Suddenly there was a surge in the height of the waves and they turned into a tsunami. What could have caused this tsunami and what were its consequences.

V. Map Work/Project

1. Make a record of recent earthquakes in India. Find out the damage caused.
2. On an outline map of the world show the world distribution of earthquakes. Mark earthquake prone areas in India.



Earthquakes

