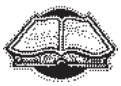


What Is This Module About?

When was the last time you felt an earthquake? Do you know what causes an earthquake? What areas in the Philippines and in the world are most likely to experience earthquakes? Would you like to know more about earthquakes?

This module is all about eartquakes—their types and causes as well as their effects on both living and nonliving things. This module is divided into two lessons. These are:

Lesson 1 – *Earthquakes: Types and Causes*

Lesson 2 – *The Effects of Earthquakes*

What Will You Learn From This Module?

After reading this module, you should be able to:

- describe how an earthquake occurs;
- identify earthquake-prone areas in the Philippines and the rest of the world;
- describe how the occurrence of an earthquake is detected and how its strength is measured;
- explain how earthquakes affect people and the environment; and
- discuss safety measures to take before, during and after an earthquake.

Let's See What You Already Know

Before you start studying this module, take the following test first to find out how much you already know about the topics to be discussed.

Write the letter of the correct answer in the blank before each number.

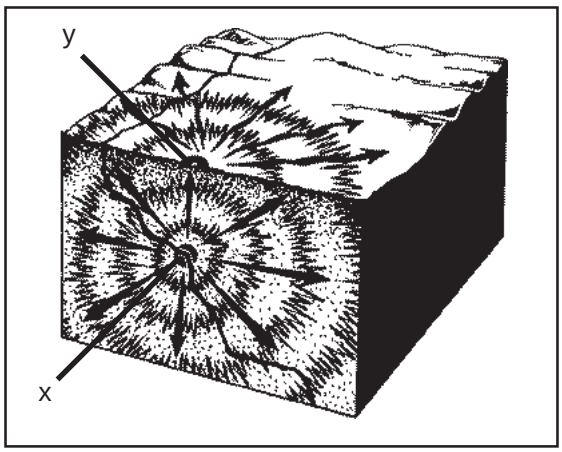
_____ 1. Giant sea waves caused by an earthquake on the ocean floor are called _____.

a. plates
b. faults
c. tides
d. tsunamis

_____ 2. The shaking and trembling that result from the sudden movement of a part of the earth's crust is known as _____.

a. landslide
b. mudflow
c. earthquake
d. tectonic plate

Study the figure below. Use it as your basis for your answers to items 3 and 4.



_____ 3. The underground point of origin of an earthquake is located at **x.** What does **x** represent?

a. focus
b. epicenter
c. magma
d. wave

_____ 4. The spot on the surface of the earth directly above **x** is **y.** What do you call **y?**

a. focus
b. epicenter
c. magma
d. wave

_____ 5. The phenomenon that results when the shaking brought on by an earthquake decreases the stiffness and strength of soil is called _____.

a. siltation
b. liquefaction
c. landslide
d. fire

_____ 6. The zone that circles the Pacific Ocean is called the Ring of Fire because there are many _____ in this area.

a. forest fires starting
b. denuded mountains
c. volcanoes erupting
d. deep valleys

_____ 7. The _____ Scale contains the values of the magnitude of an earthquake.

a. Celsius
b. Richter
c. Mercalli
d. Rossi-Forel

_____ 8. The destructive effects of an earthquake are indicated by its intensity.

a. True
b. False

_____ 9. When an earthquake has a magnitude of 8 on the Richter Scale, how will you describe its effects on areas near the epicenter?

a. damaging shocks
b. destruction in populated areas
c. serious damage to buildings
d. destroyed communities

_____ 10. What is the safety measure that people should observe before an earthquake occurs?

a. Conduct fire drills.
b. Conduct earthquake drills.
c. Conduct military drills.
d. Conduct calisthenics drills.

Well, how was it? Do you think you fared well? Compare your answers with those in the *Answer Key* on page 39 to find out.

If all your answers are correct, very good! This shows that you already know much about the topics in this module. You may still study the module to review what you already know. Who knows, you might learn a few more new things as well.

If you got a low score, don't feel bad. This means that this module is for you. It will help you understand some important concepts that you can apply in your daily life. If you study this module carefully, you will learn the answers to all the items in the test and a lot more! Are you ready?

You may go now to the next page to begin Lesson 1.

Earthquakes: Types and Causes

When you throw a pebble into a pond, waves radiate outward in all directions on the surface of the water. Similarly, when rocks in the earth's crust break, earthquake waves travel through the earth in all directions. The ground shakes and trembles. During a strong earthquake, the ground can rise and fall like waves on an ocean. The motion of the ground causes buildings, trees, electrical and telephone posts to sway and fall. Loud noises can sometimes be heard coming from deep within the earth.

Would you like to learn more about earthquakes? This lesson will teach you many things about earthquakes. You will find out how an earthquake occurs, how its occurrence is predicted and its strength measured. You will also learn more about areas in our country and in the rest of the world where earthquakes occur regularly.

Let's Try This

Do you know how to make a stick move back and forth? Do the following activity:

1. Get a wooden stick.
2. Hold the ends of the stick with both hands.
3. Bend the stick slowly.
4. Continue applying force on the stick until it breaks. Take note of the movement of the stick as it breaks.

Let's Think About This

The activity you did shows what happens when an earthquake occurs.

1. What caused the stick to bend?

   _____

   _____

2. Describe what happened to the stick right after it broke.

   _____

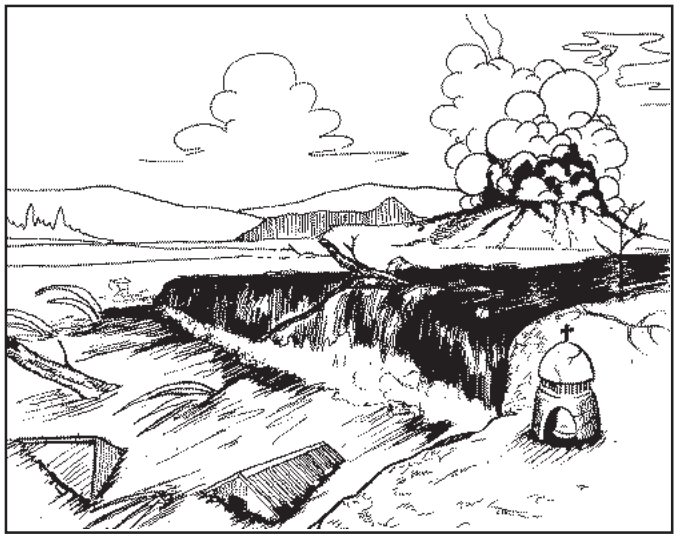
   _____

Compare your answers with those in the *Answer Key* on page 39.

Let's Learn

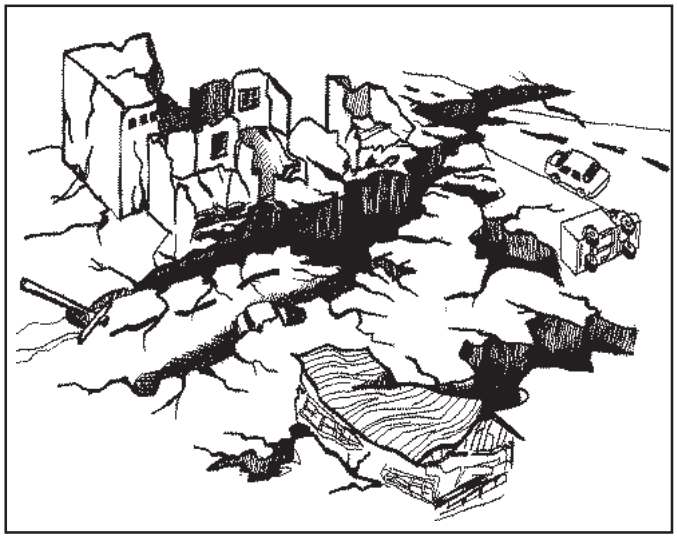
What causes earthquakes? Did you know that there are two types of earthquakes? These are volcanic earthquakes and tectonic earthquakes.

Volcanic earthquakes are earthquakes caused by volcanic eruptions. The effects of volcanic earthquakes are usually felt only in areas around the erupting volcanoes.



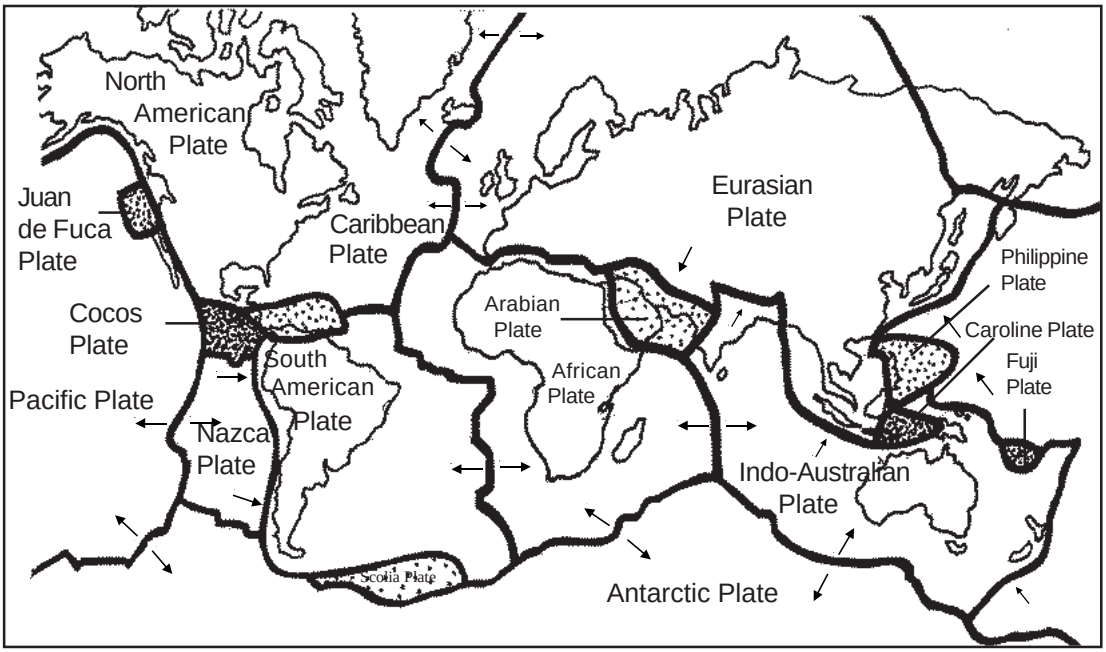
Volcanic earthquakes occur as a result of volcanic eruptions.

Tectonic earthquakes occur when there is movement under the earth's crust. They occur over a wider area than volcanic earthquakes.



The effects of a tectonic earthquake are seen over a large area.

You will understand this better if we discuss the theory of plate tectonics. This theory tells us that the earth's lithosphere is made up of separate plates that are in constant motion. These plates, called **tectonic plates,** are like pieces of a jigsaw puzzle that fit together.



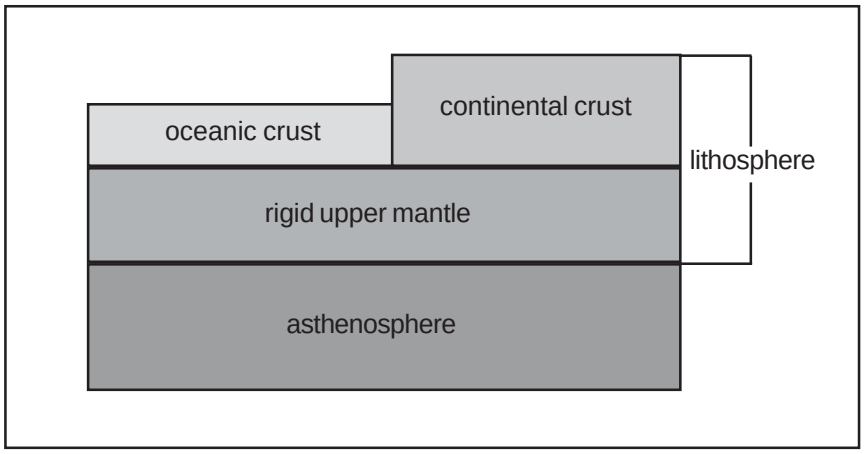
The earth's lithosphere is made up of plates that are constantly moving. The arrows point to the directions in which the plates are moving.

To understand the theory of plate tectonics better, let us first discuss the composition of the earth. Do you know how the inner layer of the earth looks? The interior of the earth is made up of three parts—the crust, mantle and core.

The **crust** is the outer layer of the earth. It is a relatively thin layer of rocks. This is the layer of the earth that is visible to us. On it we find mountains, hills, valleys, plains and even bodies of water. This outer layer is thickest in the continents (the land part of the earth) and thinnest in the oceans.

The layer underneath the crust is the **mantle.** It is made up of rock materials, although part of the upper mantle is actually a layer of semi-liquid molten rock called **magma.** This molten material flows slowly underneath the crust.

The **core** is the innermost part of the earth. The outer core is made up of liquid iron while the inner core is made up of solid iron.

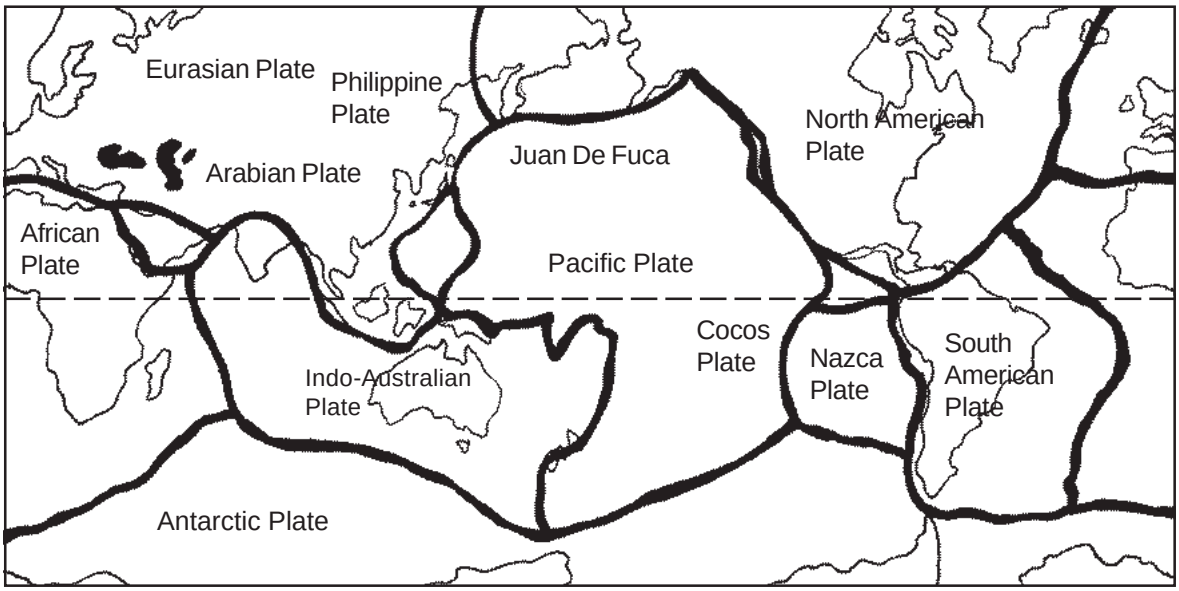


The earth's outer layer is the lithosphere. It is made up of the rigid upper mantle and the crust. The asthenosphere is the part of the mantle that flows, and it is on this that the lithosphere moves.

The crust and the solid upper mantle are what make up the **lithosphere.** According to the plate tectonics theory, the lithosphere is made up of plates, each about 100 kilometers (km) thick, which float upon a hot, soft rock layer called the **asthenosphere.** If you would like to know how the lithosphere looks, imagine several slabs of ice floating on water. The slabs of ice are the plates, while the water is the asthenosphere.

There are two types of plates—the continental and oceanic plates. The continental plates make up the land part of the earth. Oceanic plates "hold" the earth's oceans. They are usually thinner but denser than continental plates.

There are nine large plates on earth, with some smaller ones around them. Study the diagram below. It shows the nine major plates and a number of minor ones, including the Philippine Plate. These plates are moving constantly in varying directions relative to each other.



The major and smaller tectonic plates of the world

The nine major plates are the North American, South American, Eurasian, African, Indo-Australian, Antarctic, Pacific, Nazca and Cocos Plates.

The smaller plates include the Philippine Plate. These plates are also very important because they, too, are responsible for the many activities on the surface of the earth.

Most plates are combinations of both oceanic and continental plates. However, the Pacific Plate is almost entirely oceanic.

Do you wonder why we don't feel the plates of the earth moving underneath us? Do you know how fast the plates move? Try imagining how fast your fingernails grow. That's how fast the earth's plates are moving. The average speed at which a plate moves in from 2 to 12 centimeters (cm) a year. No wonder we hardly ever notice this movement! And yet, these movements are able to cause drastic changes on the surface of the earth. Because of these movements, mountains and volcanoes are formed, continents are divided and new islands are born.

It is not yet known what exactly causes the plates to move, but a lot of scientists believe that the reason for this is the high temperature in the earth's inner core, which heats up the mantle. The heat causes **convection currents,** which are rising and sinking movements, in the magma. The magma rises and spreads out then cools and sinks, dragging along the plates attached to it.

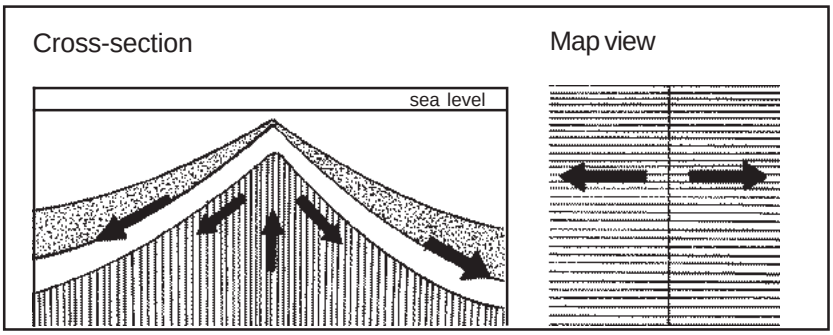
Convection causes plate motion. This constant plate motion puts stress on the lithosphere. When this stress is great enough, the lithosphere breaks or shifts. Do you recall the activity you performed in "Let's Try This" on page 5? The stick represents the lithosphere and the force you applied to it represents the stress caused by plate movements. When you put too much force on the stick, the stick broke. In the same way, when there is too much stress on the earth's crust, an earthquake occurs. When stress is released, a tremendous amount of energy in the form of an earthquake is released along with it.

> Did you know that earthquakes occur every day? In fact, several million earthquakes occur every day. The constant shifting of the earth's lithosphere is responsible for this. Fortunately for us, most of these earthquakes are too small for us to feel.

Earthquakes most often occur along plate boundaries. **Plate boundaries** are areas where plates meet. There are three types of plate boundaries, depending on the movement of the plates—divergent, convergent and transform plate boundaries.

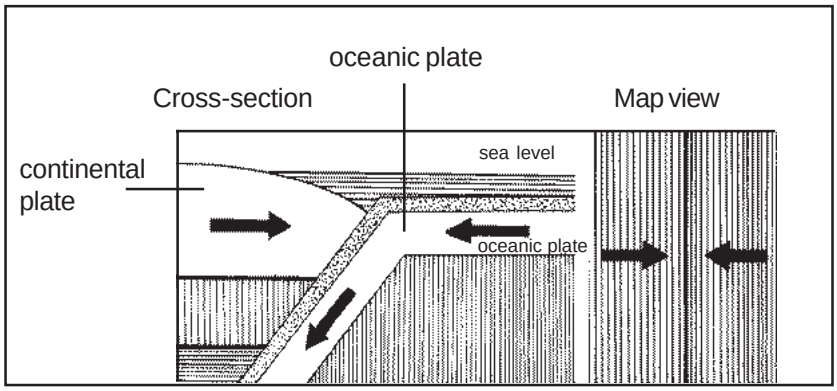
The first type of plate boundary is the **divergent boundary** or spreading center. At this type of boundary, the plates are moving away from each other. As the two plates move apart, magma rises from the mantle and mid-ocean ridges are created. **Mid-ocean ridges** are vast mountain chains found in the ocean. This in turn leads to the creation of new crust on either side of the vent.

The pull-apart motion along divergent boundaries creates tension in the plates. The crust eventually breaks and an earthquake occurs. However, because most rocks are weaker when pulled apart than when compressed or pushed together, earthquakes along divergent boundaries tend to be weak and small.



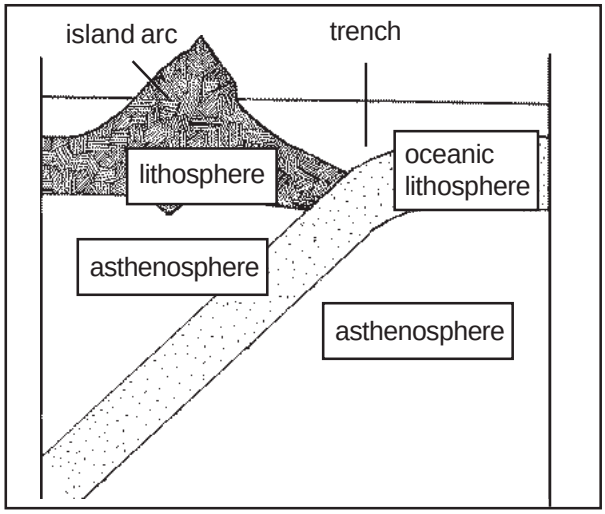
In a divergent plate boundary, two plates are moving away from each other, as indicated by the arrows.

The second type of plate boundary is the **convergent boundary** or **subduction zone.** This boundary occurs when two plates move toward each other. When the two plates collide, one of three things can happen, depending on the type of plates that converge. When an oceanic plate collides with a continental plate, the oceanic plate goes down into the mantle and melts partially because of the magma. The magma finds an opening through which to come out, hence a **volcano arc** (a chain of volcanoes) is formed.



In a convergent plate boundary, two plates move toward each other. When an oceanic plate collides with a continental plate, the oceanic plate goes down into the mantle as indicated in the diagram on the left.

When an oceanic plate collides with another oceanic plate, an **island arc** is formed. An island arc is a curved chain of oceanic islands. The Philippines is an example of an island arc. This also leads to the formation of trenches. A **trench** is the deepest part of an ocean.

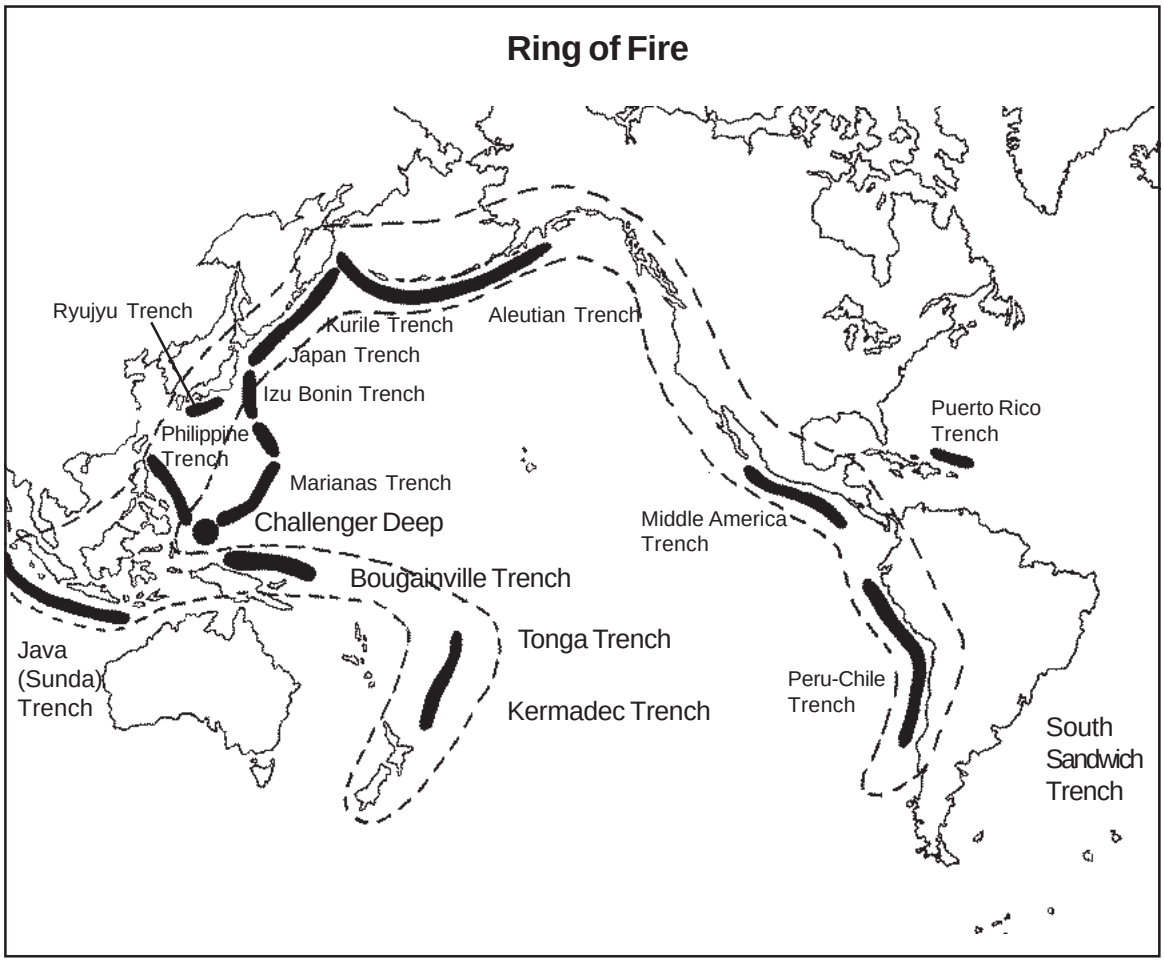


Collision between two oceanic plates leads to the formation of island arcs and trenches.

When two continental plates collide, a mountain range is formed. For instance, the Himalayas, which is the famous mountain range in India, was formed when the Indian Plate collided with the Eurasian Plate.

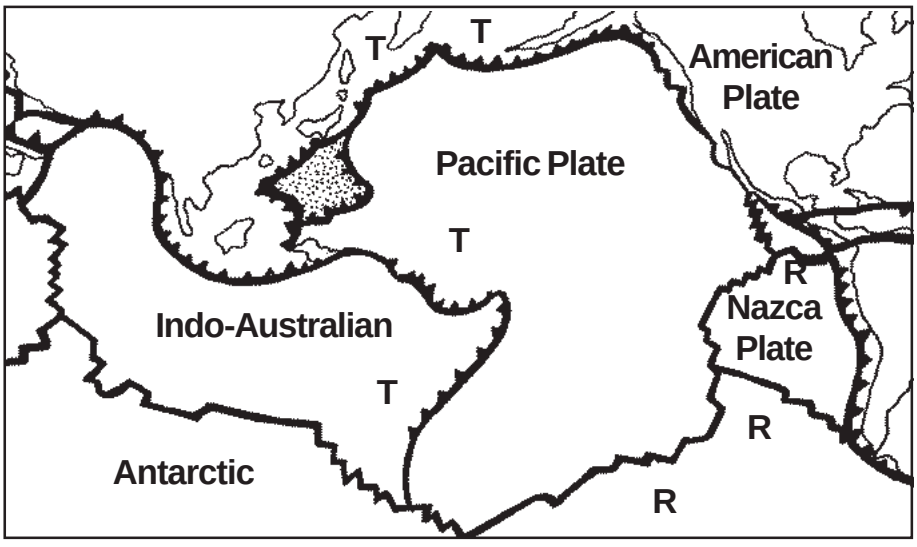
The collision process in convergent boundaries leads to compression or the pushing together of rocks on the earth's crust. This action is the reason why the strongest earthquakes occur in subduction zones. Hence, the Philippines is an earthquake-prone area.

Do you know the Ring of Fire? The **Ring of Fire** is a zone of frequent earthquakes and volcanic eruptions around the Pacific Ocean. Our country is included in this zone. The ring stretches from the tip of South America, up the west side of South, Central and North America, down to Japan, the Marianas Islands, Indonesia, Papua New Guinea, Tonga and ends at New Zealand. Look at the picture on page 12.



The Ring of Fire is found around the Pacific Ocean. Did you notice that there are plenty of trenches in this zone?

Do you know why there are plenty of trenches in the Ring of Fire? There are plenty of trenches here because of the subduction in the Pacific Plate.

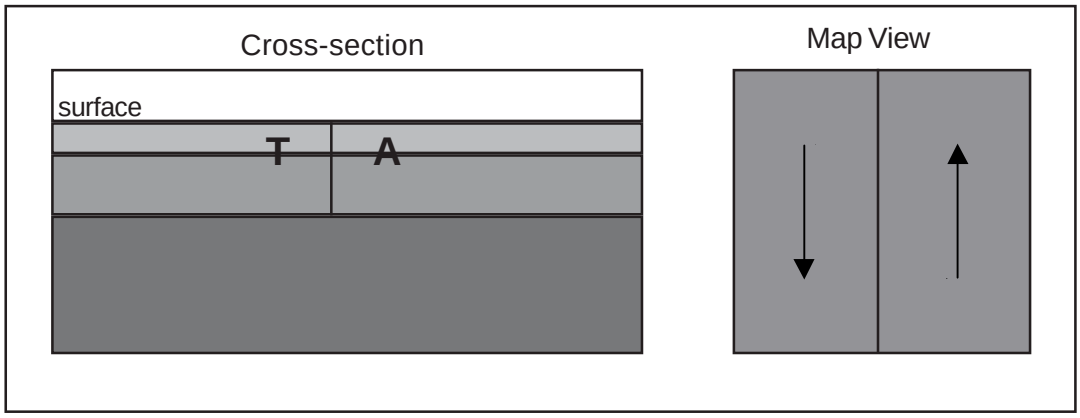


The Pacific Plate collides with the Indo-Australian and North American Plates, hence, the formation of trenches (T) around the zone. It also moves away from the Antarctic Plate, leading to the formation of mid-ocean ridges (R).

Let's look more closely at the Pacific Plate of which the Philippines is a part. The Pacific Plate collides with the Indo-Australian and North American Plates. Being an oceanic plate, part of the Pacific Plate has gone under the two continental plates. Hence, there are plenty of subduction zones in this plate, forming the Ring of Fire. There are also plenty of island arcs, namely, the Aleutian, Japan, Ryukyu, Pacific and Marianas Arcs.

There are also plenty of subduction zones in the minor plates. For instance, the Philippine Plate which is found east of our country and the Eurasian Plate which is on the west are two colliding plates. In fact, the Philippines was formed from the subduction of these plates. This subduction is also responsible for the strong earthquakes in Japan.

A **transform plate boundary** is one where two plates slide past each other. Movement is not smooth because of friction between the rocks of the two plates and this sometimes leads to the two plates getting stuck and locked together. Because the convection currents are still dragging the plates, much tension and pressure are built up at the transform boundary. When there is sufficient pressure already, the rocks in the plates break and get jerked apart. This leads to earthquakes.



In a transform plate boundary, one plate is moving toward a certain direction (T) while the other plate is moving toward the opposite direction (A).

Let's Review

Let's find out how much you understood from the discussion. Write the letter of your choice on the line before each number.

_____1. The three layers of the earth are the _____.

a. core, asthenosphere and mantle
b. crust, mantle and core
c. crust, magma and core
d. mantle, core and magma

_____2. The driving force for the movement of the earth's plates is _____.

a. conduction
b. stress
c. radiation
d. convection

_____3. A _____ occurs when two plates are moving away from each other.

a. divergent plate boundary
b. subduction zone
c. convergent plate boundary
d. mid-ocean ridge

_____4. When two continental plates collide, a _____ is formed.

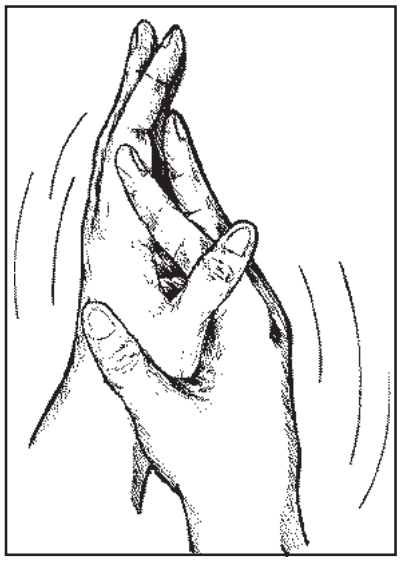
a. mountain range
b. volcano arc
c. mid-ocean ridge
d. trench

_____5. The strongest earthquakes occur in the _____.

a. transform plate boundary
b. subduction zone
c. divergent plate boundary
d. island arc

Compare your answers with those in the *Answer Key* on page 39.

Let's Try This



Here's another activity you can do in order to simulate an earthquake. Place your hands together with your thumbs up. Push your hands together. When you do this, you create pressure between your hands. As you try to slide your hands apart, you create friction which stops you from sliding your hands easily. Stress builds in your hands and arms as well.

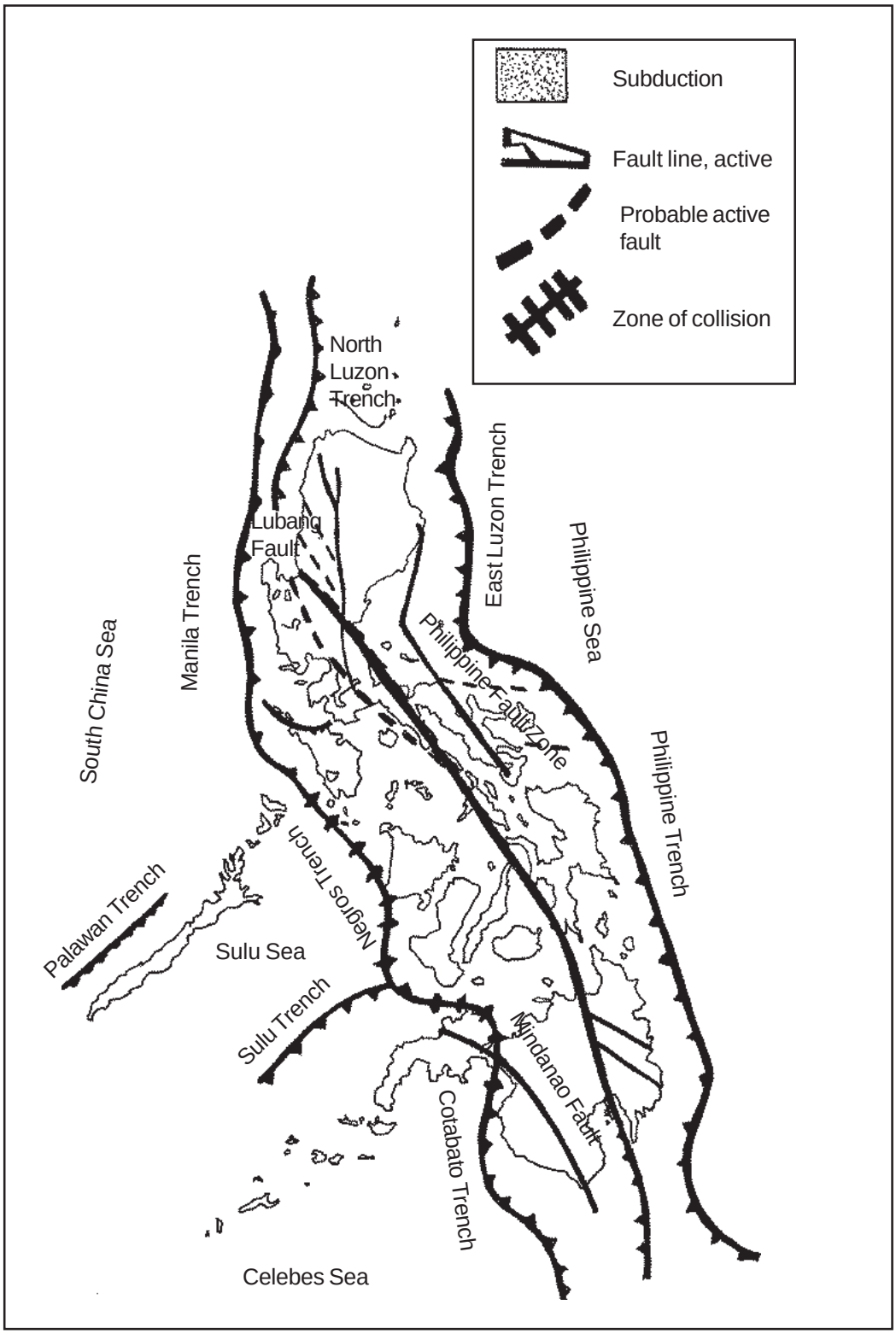
What do you think your hands represent? Read on to find out.

Let's Learn

Faults are areas on the crust where fractures are created by the motion of the plates. They are the ones that absorb the motion of the plates. It is on faults where stress builds up.

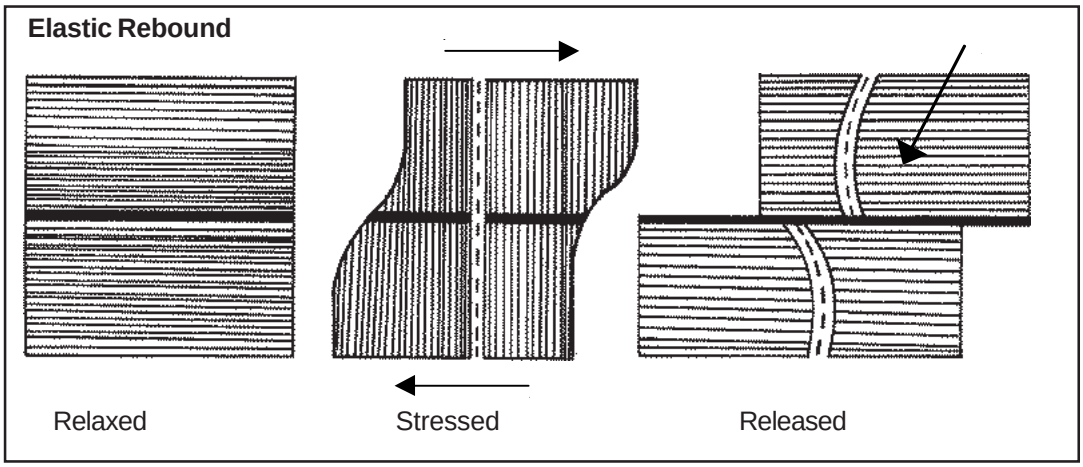
Faults are narrow zones which separate blocks of crust. A well-known fault is the San Andreas Fault which separates the Pacific Plate from the North American Plate. The Pacific Plate has San Francisco and Los Angeles on it, hence, earthquakes occur frequently in these two districts in the U.S.A.

On the other hand, the Philippine Fault runs from Lingayen Gulf to Eastern Mindanao. Deep earthquakes can occur along this fault especially in Luzon and Mindanao. Hence, the largest earthquakes in the twentieth century took place in these areas. Look at the map on the next page. You can see that the Philippines has plenty of fault zones, trenches and troughs that are sites of active movements of the earth's crust. (A trough is an elongated depression in the earth's crust that is bounded by faults.)

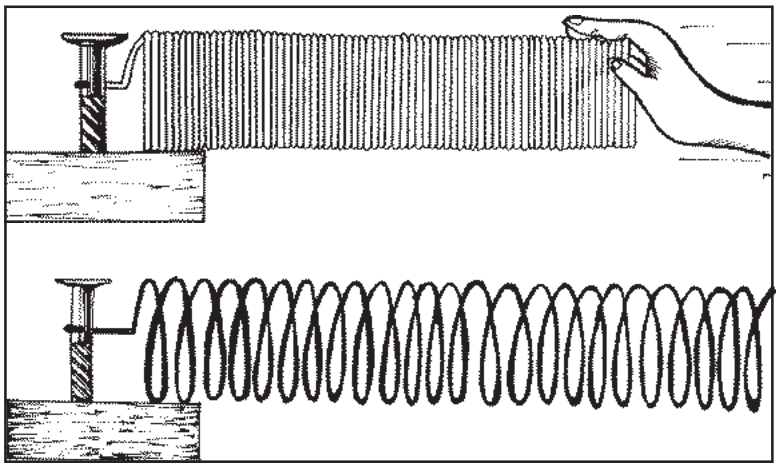


The major seismic zones of the Philippines are found in the subduction zones and faults.

Faults resist the forces that try to move the plates apart. As the forces build up, the fault remains locked and the blocks of crust get deformed because of the stress. Eventually the stresses get so high that the fault breaks in order to release the stress. Release of the stress allows the sides of the fault to slide past each other. This sliding motion is what we experience as an earthquake.

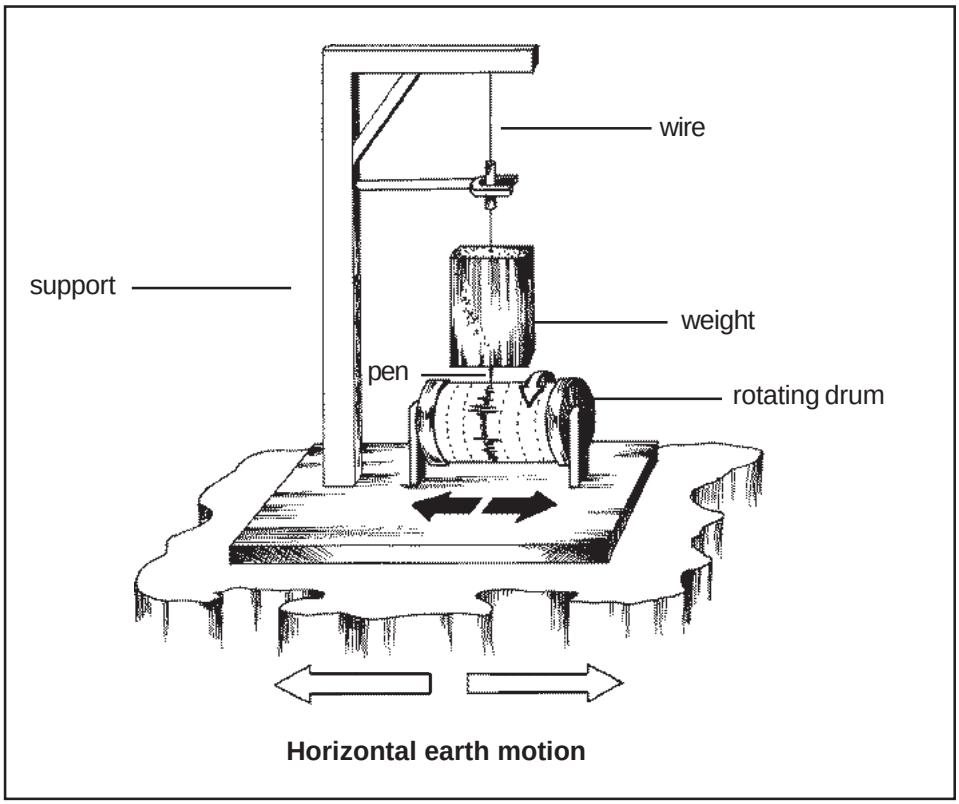


When the limit for stress is reached, the rocks along a fault move suddenly and the stress is released as elastic energy. Imagine a spring, like the one shown below. When you put your hand down on the spring, you are putting stress on the spring. When you release your hold on the spring, it bounces up. This is because the energy stored in the spring is released. This is how the earth's crust moves during an earthquake.



Do you recall the activity on page 15? Do you know what your hands represent? Your hands represent the sides of a fault moving against each other. After a while, it became difficult for you to keep rubbing your hands against each other. The same thing happens to two blocks of crust that are sliding past each other—they become locked against each other. Continuous buildup of pressure leads to more stress along the fault, causing the fault to break.

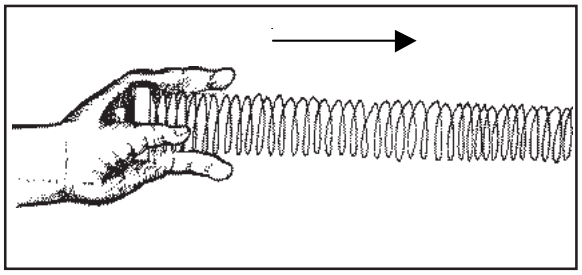
When an earthquake occurs, it pumps seismic waves into the surrounding rock. **Seismic waves** are the form in which energy released by an earthquake travels. These waves can travel all around the world and can be measured by an instrument called **seismograph.**



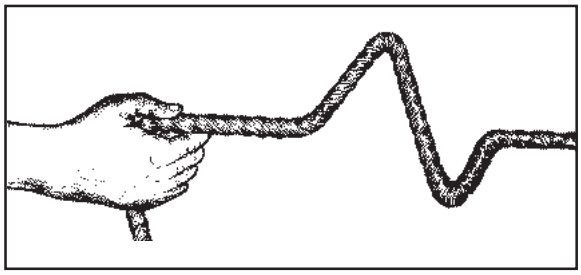
The seismograph is used to measure the strength of an earthquake.

There are two basic kinds of seismic waves—body waves and surface waves. **Body waves** travel within the earth. They travel outward in all directions from the **focus,** the particular spot where the fault began to break. **Surface waves,** on the other hand, travel only on the surface of the earth. They travel parallel to the surface, similar to how ripples travel on the surface of a pond. They are also slower than body waves.

The body waves strike first when an earthquake takes place. The fastest kind are the **primary** or **P waves.** Perhaps you have heard a trainlike sound just before you felt an earthquake. That was the P wave moving in the air as an acoustic wave. P waves can travel through gases, liquids or solids. After the P waves, the **secondary** or **S waves** are the next to arrive.



P waves can be likened to the movement of a Slinky toy.



S waves move in a shear motion.

S waves are felt as a powerful jolt. If you are in a building when an earthquake strikes, the arrival of the S waves would feel as if a giant has pounded his fist down on the roof.

Afterward, the surface waves strike. These waves cause up-and-down and back-and-forth motions that make the ground appear to roll and can topple buildings over.

Let's Review

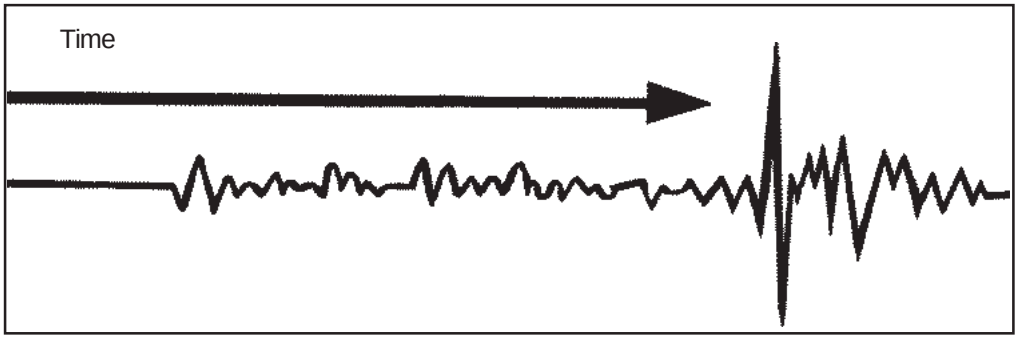
1. What is the difference between body waves and surface waves?

   _____

   _____

   _____

2. The picture below shows a seismogram which is a record of the shaking of the ground caused by an earthquake. Identify the P waves and S waves on the seismogram.

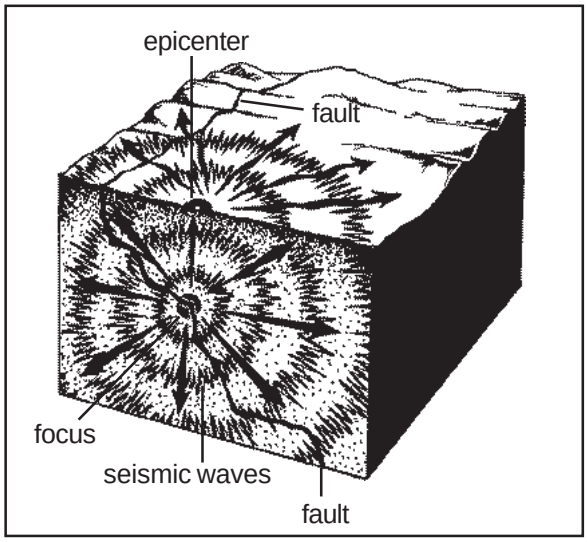


Compare your answers with those in the *Answer Key* on page 40.

Let's Learn

Locating Earthquakes

Seismology is the study of earthquakes, their causes as well as their effects. Seismologists are able to locate an earthquake by examining the seismogram, which is a record of the shaking of the ground made by the seismograph. Through the seismogram, seismologists are also able to determine the focus and epicenter of the earthquake. The **focus** of an earthquake is the specific spot on the fault from which the earthquake originates, while the **epicenter** is the spot on the earth's surface that is directly above the focus.



The focus and epicenter of an earthquake

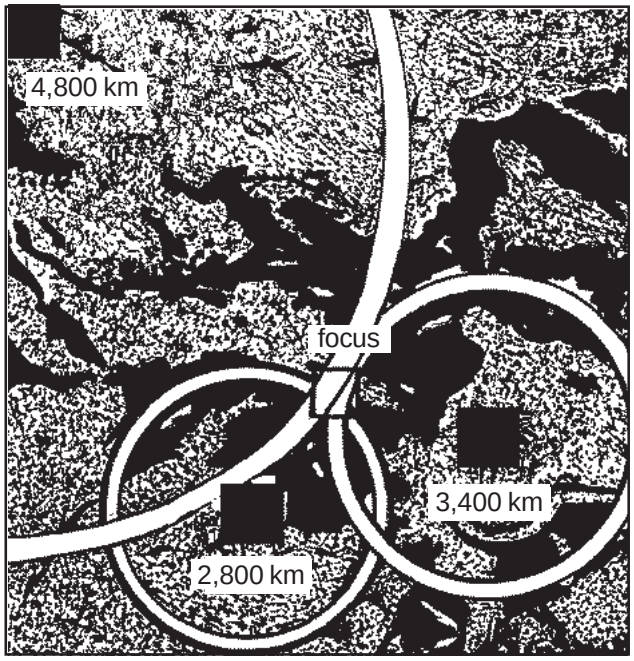
As we mentioned earlier, the seismogram shows the pattern of seismic waves. Seismologists locate earthquakes by measuring the difference between the time of arrival of the P waves and that of the S waves.

P waves travel almost twice as fast as S waves and hence will arrive first at the seismological station. If you know the speed of the waves through the crust in a particular area and you have a seismograph that records the arrival of the shocks, you will be able to compute the distance of the station from the focus of the earthquake.

In order to come up with an accurate reading of the earthquake's point of origin, seismograms from at least three stations are needed. The radii of the circles drawn from the three foci to the stations are measured. The point at which the three circles intersect is the focus of the earthquake.

Let's Think About This

Let's imagine that there are three seismological stations that were able to record a certain earthquake. One station detected the earthquake at a distance of 4,800 km; another station recorded the distance of the earthquake as 2,800 km; and the third station recorded the distance as 3,400 km. Where do you think the focus of the earthquake is?



In order to determine the epicenter of the earthquake, the seismologists in the three stations drew circles using the location of their respective stations as the center (black squares) and their recorded distances as the radii. The point at which the three circles intersect is the focus of the earthquake, as indicated by the black square outline in the diagram above.

Let's Learn

Predicting Earthquakes

Can we predict earthquakes? What do you think? Seismologists have found some warning signals that help predict earthquakes. Sometimes slight changes in the tilt of the earth's surface can be detected by sensitive instruments. Geologists also note that land near a fault may rise or sink slightly. The water level in wells will often go up or down when an earthquake is about to occur.

Scientists continue to study earthquakes in the hope of improving their ablity to predict these accurately. Earthquake prediction must be reliable and complete. The information must include where, when and how strong the earthquake will be. If a strong earthquake is predicted, areas in danger can be evacuated.

If strong earthquakes could be predicted years in advance, people could plan their places of residence and business better. Buildings could be reinforced to better withstand the shock from an earthquake.

The goal of short-range earthquake prediction is to provide people a means of knowing the location and magnitude of a large earthquake that will occur within a short period of time. Substantial efforts to achieve this objective are being made in the United States, Japan, China and Russia, countries where earthquake risks are high. Scientists in these countries want to find out what possible precursors or events come ahead that serve as a warning that an earthquake is coming. In California, for example, some seismologists are measuring **uplift** (rising of a portion of the earth's crust), **subsidence** (lowering of a portion of the earth's crust) and strain in the rocks near active faults.

Some Japanese scientists are studying peculiar behavior among animals that may precede an earthquake. Do you recall the incident when about five trucks of jellyfish were fished out from a river near the Napocor plant in Sual, Pangasinan? A few hours later, an earthquake was felt in several provinces and cities. Some people living near Mayon Volcano also claim to have seen snakes coming down from the volcano before it erupted.

Can you think of examples of anomalous animal behavior?

Some of these include fish "jumping" into a lake, dogs howling, ducks and geese quacking continuously and animals like snakes going down into volcanoes.

Measuring Earthquakes

Early attempts to establish the intensity of an earthquake relied much on description of the events. **Intensity** is an indication of the destructive effects of an earthquake on a particular place. Intensity is affected by such factors as distance from the epicenter and the nature of surface materials. This can of course cause confusion because people's experiences of one earthquake event will vary depending on their location and the kind of surface they live on.

In1902, a fairly reliable scale based on the amount of damage on structures was developed by Guiseppe Mercalli. Later on it was modified by the U.S. Coast and Geodetic Survey. See the table on the next page.

Modified Mercalli Intensity Scale	
I.	Not felt except by very few.
II.	Felt only by a few persons at rest, especially on upper floors of buildings.
III.	Felt quite noticeably indoors especially on upper floors of buildings but many people do not recognize it as an earthquake.
IV.	Felt indoors by many, outdoors by few. Sensation like heavy truck striking building.
V.	Felt by nearly everyone, can rouse many from sleep. Disturbances of trees, poles and other tall objects sometimes noticed.
VI.	Felt by all; many are frightened and run outdoors. Some heavy furniture moved; few instances of fallen plaster or damaged chimneys. Damage slight.
VII.	Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures.
VIII.	Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures.
IX.	Damage considerable in specially designed structures. Buildings shifted off their foundations. Ground cracked considerably.
X.	Some well-built wooden structures destroyed, most masonry and frame structures destroyed with foundations. Ground badly cracked.
XI.	Few, if any, of the structures remain standing. Bridges destroyed. Broad fissures in the ground.
XII.	Damage total. Waves seen on ground surfaces. Objects thrown upward into the air.

Another scale for measuring the intensity of an earthquake is the Rossi-Forel Scale.

Rossi-Forel Scale of Earthquake Intensities		
I.	Hardly perceptible	Felt only by experienced observers and recorded only by a single seismograph or by seismographs of the same kind.
II.	Extremely feeble shock	Felt by a small number of persons at rest.
III.	Very feeble shock	Felt by several persons at rest; duration and direction are perceptible; sometimes dizziness or nausea will be felt.
IV.	Feeble shock	Felt generally indoors, outdoors by a few; hanging objects swing slightly; creaking of frames of houses.
V.	Shock of moderate intensity	Felt by everyone; hanging objects swing freely; toppling of tall trees and unstable objects; light sleepers awaken.
VI.	Fairly strong shock	General awakening of those asleep; some frightened persons leave their houses; swinging of hanging lamps; slight damages in very old or poorly built structures.
VII.	Strong shock	Toppling of movable objects; general alarm; all run outdoors; damage slight in well-built structures, old walls, etc.; some landslides from hills and steep lands; cracks on road surfaces.
VIII.	Very strong shock	People panicky; trees shaken strongly; changes in the flow of springs and wells; sand and mud ejected from fissures in soft ground; small landslides.
IX.	Extremely strong shock	Panic general; partial or total destruction of some buildings; fissures in the ground; landslides and rock falls.

However, destruction wrought by earthquakes also depends on the distance of a locality from the epicenter, the nature of surface materials and building design. Thus, methods were devised which determine the total amount of energy released during an earthquake. The measurement is referred to as **magnitude.** The **Richter Scale** is widely used to describe the magnitude of an earthquake. This scale has room for the maximum motion that can be recorded by seismic instruments, that is, there is no upper limit to the highest magnitude of an earthquake. So far, no earthquake has ever been recorded with a magnitude higher than 9. An earthquake with a magnitude greater than 4.5 can already be destructive.

Earthquake Magnitude and Effects (Richter Scale)	
Magnitude	**Effect**
2.5	Generally not felt but recorded
4.4	Local damage
6.0	Can be destructive in populated areas
7.0	Major earthquakes; inflict serious damage
8.0	Great earthquakes; occur once every 5–10 years; produce total destruction in nearby areas

Can you guess what the magnitude of this earthquake is?

Let's See What You Have Learned

Write the letter of the correct answer in the blank before each number.

_____ 1. An earthquake can either be _____ or _____.

a. tectonic; mountainous
b. tectonic; volcanic
c. volcanic; oceanic
d. volcanic; island

_____ 2. What causes a tectonic earthquake?

a. sudden movement of rocks in the earth's crust
b. formation of hills and mountains
c. continuous eruption
d. volcanic eruption

_____ 3. Mt. Mayon has been active for several years now. What will people living near it feel when it erupts?

a. landslide
b. storm surge
c. tectonic earthquake
d. volcanic earthquake

_____ 4. What occurs when there are tectonic and volcanic activities in the earth's crust?

a. typhoon
b. earthquake
c. storm surge
d. landslide

_____ 5. Which of the following describes the intensity of an earthquake?

a. duration of the shaking
b. distance from epicenter
c. highest near epicenter
d. lowest near epicenter

_____ 6. Which of the following is **not** an indication of an earthquake?

a. peculiar movements and behavior of some animals such as snakes and jellyfish
b. lowering of a portion of the earth's crust
c. rising of a portion of the earth's crust
d. drastic changes in the weather

_____ 7. Which of these is likely to happen when an earthquake with a magnitude of 7 occurs?

a. heavy rainfall
b. changes in temperature
c. roaring of thunder
d. serious damages on structures and other properties

_____ 8. Earthquakes occur frequently in our country because the Philippines _____.

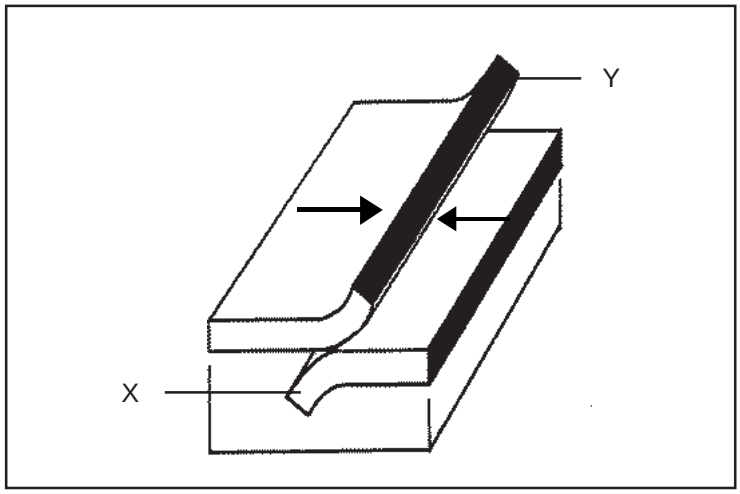
a. lies in Antarctica
b. is near China Sea
c. lies within the Ring of Fire
d. is part of the Mediterranean Sea

_____ 9. The more destructive earthquakes along the Philippine Fault are found in _____.

a. Luzon, Masbate and Mindanao
b. Luzon, Samar and Mindanao
c. Luzon, Leyte and Mindanao
d. Luzon, Bicol and Mindanao

_____10. Look at the diagram below. **X** and **Y** represent _____.

a. asthenosphere and plate
b. mid-ocean ridge and asthenosphere
c. subduction zone and mid-ocean ridge
d. plate and mid-ocean ridge



Compare your answers with those in the *Answer Key* on pages 40 and 41. Did you get a perfect score? If you did, that's very good! You may now move on to Lesson 2. If you did not get everything right, that's okay. Review the parts of the lesson that you did not understand well. Afterward, you may proceed to Lesson 2.

Let's Remember

- There are two kinds of earthquakes—volcanic and tectonic earthquakes.
- Tectonic earthquakes are brought about by the movement of the earth's plates. There are three kinds of plate boundaries—divergent, convergent and transform boundaries.
- The earth is made up of three layers—the crust, mantle and core. The crust and upper mantle make up the earth's lithosphere. The lithosphere is made up of plates that move on the soft asthenosphere.
- The movements of the plates are caused by convection that occurs in the magma.
- In a divergent plate boundary, two plates move away from each other. This leads to the formation of mid-ocean ridges.
- In a convergent plate boundary, two plates collide with each other. When an oceanic plate collides with a continental plate, a volcano arc is formed. When two oceanic plates collide, an island arc is formed. When two continental plates collide, a mountain range is formed.
- The Ring of Fire is a zone of frequent earthquakes and volcanic eruptions. The Philippines is part of this ring.
- A transform plate boundary is one where two plates slide past each other. Earthquakes occur frequently on this type of boundary.
- Faults are narrow zones that separate blocks of crust. They absorb the motion of the plates. When there is too much stress on a fault, the fault breaks and an earthquake occurs.
- Seismology is the study of earthquakes and their effects. The strength and location of an earthquake can be detected from the seismogram, a graphic record of the reading taken by the seismograph.
- Seismic waves are the form of energy in which an earthquake travels. There are two types of seismic waves—body waves and surface waves. The P waves and the S waves are body waves.
- The focus of an earthquake is the specific spot on the fault from which the earthquake originates, while the epicenter is the spot on the earth's surface that is directly above the focus.
- The intensity of an earthquake is measured by its effects on a particular location. It is measured on the Mercalli Scale and Rossi-Forel Scale. The magnitude of an earthquake, on the other hand, is a measure of the amount of energy released during an earthquake. It is measured on the Richter Scale.

The Effects of Earthquakes

Have you ever experienced an earthquake? Did you feel the earth move? Did you get dizzy? Did objects around you fall? Did you get scared? Earthquakes can be very scary at times.

Would you like to learn more about earthquakes and how they affect us and our environment? This lesson will help you understand how earthquakes affect people and the environment. You will also find out what safety measures you could follow in case an earthquake occurs.

Let's Try This

Would you like to know about one immediate effect of a strong earthquake?

1. Get a drinking glass half-filled with a soft drink.
2. Shake the glass for one minute. Observe what happens to the soft drink.

Let's Think About This

The activity you performed shows what happens to a body of water during an earthquake.

1. What happened to the soft drink in the glass after you shook the glass?

   _____

   _____

2. What does your shaking action represent?

   _____

   _____

3. If an earthquake were to occur on an ocean floor, what do you think would happen?

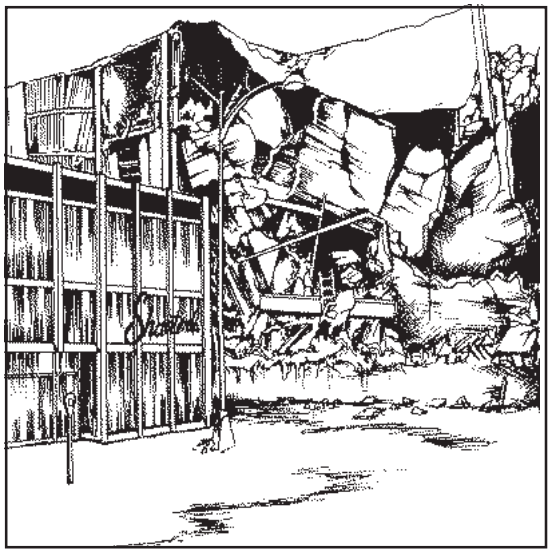
   _____

   _____

Compare your answers with those in the *Answer Key* on page 41.

Let's Learn

An earthquake can be a very frightening experience for anyone. When a strong earthquake takes place, there can be great losses in lives and property. Trees fall, electric posts sway, wires snap and so on.



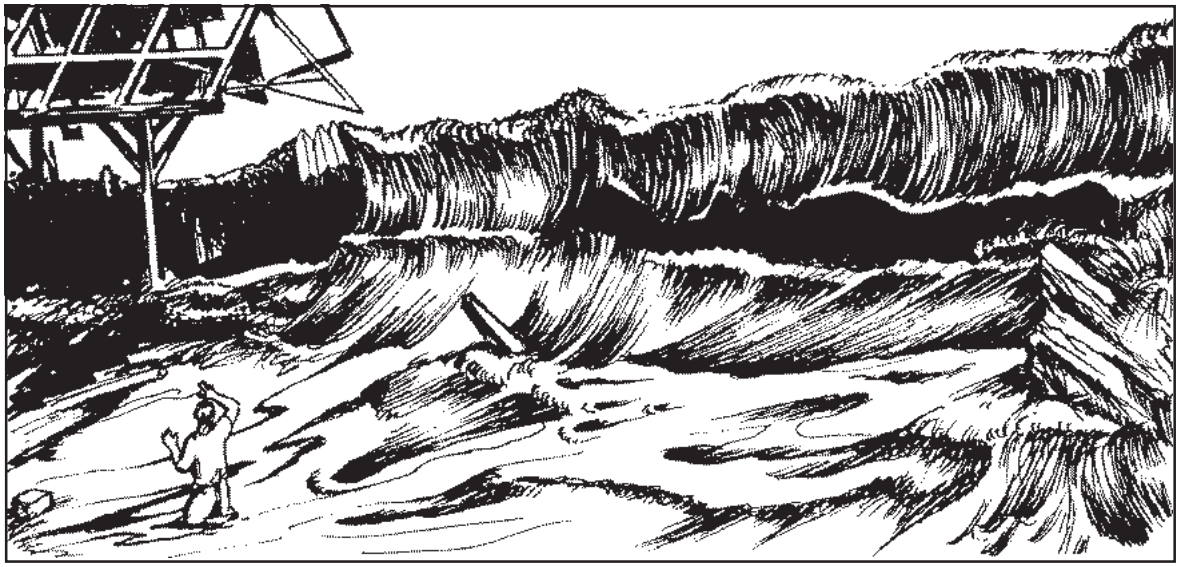
Damage caused by an earthquake

Buildings destroyed by a strong earthquake

Earthquakes produce various damaging effects on the areas they act upon. The worst cases lead to loss of lives and heavy structural damages.

Tsunami

Do you know what a tsunami is? A **tsunami** is a huge, fast-moving wave that originates on the ocean floor when an earthquake occurs in that area.



A tsunami can destroy property and lead to loss of lives.

When an earthquake occurs on the ocean floor, waves spread out from the shock center like ripples from a stone dropped into water. But the waves spread out at speeds that can reach 720 km per hour. The average distance between these waves is about 300 km. Because of their rapid movements, tsunamis are very deadly and destructive.

Did you know that a tsunami hit Southern Mindanao in the 1970s? In August 1976, an earthquake of magnitude 8 struck Mindanao with its epicenter in the Gulf of Moro in the Celebes Sea. A large tsunami was generated by the earthquake and hit several communities in Sulu, Zamboanga, Lanao, North Cotabato and Maguindanao. It killed around 10,000 people.

Destruction of Buildings

In the late afternoon of July 16, 1990, a tremor registering 7.8 on the Richter Scale struck Northern Luzon, leaving many parts of the country's main island in ruins. It was the second most destructive earthquake to hit the country in the last 45 years, claiming 1,283 lives and injuring almost 3,000.

The 1990 tremor was felt from Ilocos to Manila. Scenes of destruction in the cities of Baguio, Cabanatuan and Dagupan and parts of Benguet and Pangasinan flooded our television screens.

In Cabanatuan City, 134 people, mostly high school students, were killed when the four-story Christian Colleges of the Philippines (CCP) building collapsed like an accordion.

Landslides

When an earthquake strikes a hilly or mountainous area, materials such as rocks and soil are loosened and start to move downhill. This results in what we call a **landslide.** Rocks and soil may fall at a very high speed. There can also be slower movements of rocks and soil as in the case of mudflow.

Because of the 1990 earthquake, more than 10,000 hectares of prime agricultural land in Nueva Vizcaya was damaged either by landslides or flashfloods. Major roads and bridges that were destroyed became a perennial problem. When the historic Dalton Pass was made impassable by the earthquake, Vizcayanos had to travel 24 hours going to Manila. Do you realize how difficult it must have been to transport people and goods like vegetables and other products from one place to another?

Liquefaction

Liquefaction is a phenomenon in which the strength and stiffness of soil is reduced by the shaking brought on by an earthquake. It occurs in soil that is filled with water. Normally, the water in the soil pushes against the soil with only a little amount of force and the soil particles do not move against one another. When an earthquake occurs, the water starts to exert a greater force on the soil particles. The force is big enough to enable the soil particles to move readily relative to one another.

Many homes and buildings are destroyed when liquefaction occurs.

When liquefaction occurs, structures on the soil are destroyed as the soil softens.

Fire

Large earthquakes can also cause fire. An earthquake can shake electric wires and uproot electrical posts. In some instances, power lines break off, thus starting fires. Pipelines in some cities may be broken during a strong earthquake. When large communities have old wooden structures, fire can cause great destruction. In the 1906 San Francisco earthquake, for instance, the fire could not be controlled for three days. The fire destroyed 500 city blocks.

The earthquake in San Francisco, U.S.A. in 1906 killed hundreds of people and almost leveled the city to the ground.

Safety Measures

The following are some points for you to remember to avoid undue loss of lives and property during an earthquake.

Before the Earthquake

Individual

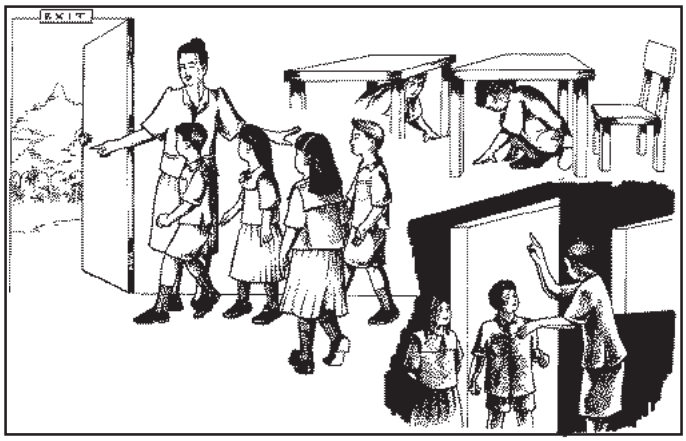
Find out if your office, school or factory has an emergency plan. If it has one, make sure that you know how the plan goes. If it doesn't have one, take the initiative to encourage your companions to make one.

Family

1. Have a battery-powered radio, flashlight and first-aid kit ready at all times. Make sure everyone knows where they are stored. Keep extra batteries on hand. Store canned goods, water and other supplies you and your family may need.
2. Learn how to perform first aid.
3. Know the location of your gas and water valves and electric fuse box. Make sure all responsible members of your family know how to turn these off.
4. Secure heavy appliances to the floor and anchor heavy furniture such as cupboards to the wall.
5. Don't put heavy objects on high shelves.
6. Devise a plan for members of your family to stay together during an earthquake.
7. Practice an earthquake drill regularly.

Community

Earthquake drills are necessary for a community, so that in case of an earthquake, everyone would know what to do.



Earthquake drill in a school

During an Earthquake

Individual

1. Stay calm and stay where you are, whether you are indoors or outdoors. Many people are injured as they enter or leave buildings.
2. If you are indoors, stand against the wall nearest the center of the building. You may also stand against a doorway or stay under a desk or some other sturdy furniture.
3. If you are in a moving vehicle, stop the vehicle and remain inside until the tremor stops.

Family

1. Make sure that every member of your family seeks shelter under a heavy or sturdy furniture.
2. Direct each member of the family to stay calm and stay away from objects or materials that may fall.

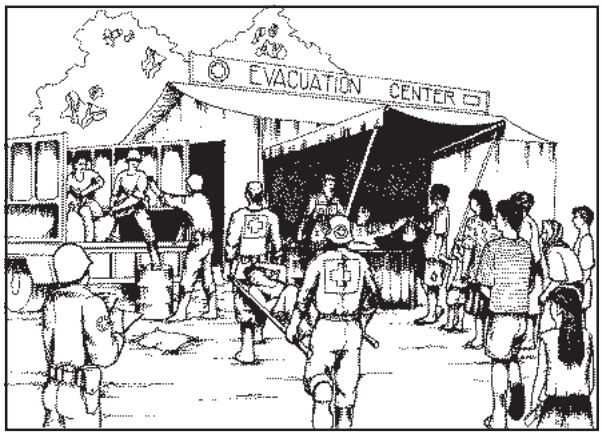
After an Earthquake

Individual

1. Check yourself and other people nearby for injuries. Administer first aid if needed.
2. Check water, gas and electric lines. If these are damaged, close the valves. Check for leaking gas by odor only. If gas is leaking, open all windows and doors, leave immediately and report the damage to authorities.
3. Turn on the radio for news updates. Use the telephone only for relaying important messages.
4. Do not flush toilets until sewer lines are checked.
5. Stay out of damaged buildings.
6. Wear boots, if you have them, to protect yourself against shattered glass and debris.

Family

1. Closely examine the members of your family for possible injuries.
2. Check for spots that are likely to catch fire.
3. Do not let the children roam around. Warn them against electrocution due to fallen live wires.



A scene after an earthquake

Let's Try This

Draw an emergency plan that your family can use in case of an earthquake. Show your plan to your Instructional Manager or Facilitator.

Let's See What You Have Learned

Write your answers on the lines provided.

1. Explain briefly how an earthquake affects people and the environment.

   _____

   _____

   _____

2. Earthquakes can take you by surprise. You have to be prepared at all times. List at least two safety measures that you should observe before, during and after an earthquake.

   Before: a. _____

   b. _____

   During: a. _____

   b. _____

   After: a. _____

   b. _____

Compare your answers with those in the *Answer Key* on pages 41 and 42.

If you got everything right, that's very good! It means you understood the lesson well. If you did not get a perfect score, that's okay. Just review the parts of the lesson that you did not understand very well.

Let's Remember

- Earthquakes can bring many destructive effects to the environment. Among these are the formation of tsunamis, destruction of buildings and other structures, landslides and liquefaction.
- You should always keep in mind the safety measures you need to follow in preparation for, during and after an earthquake.

You have now reached the end of the module. Congratulations! Did you enjoy studying this module? Did you learn a lot from it? The following is a summary of its main points to help you remember them better.

Let's Sum Up

This module tells us that:

- Earthquakes are caused by the movements of the earth's tectonic plates, whose motions are powered by convection currents.
- An earthquake occurs as a result of the buildup of stress along a fault, causing the fault to rupture.
- The Philippines, having several active faults and being part of the Ring of Fire, is an earthquake-prone country.
- The location and strength of an earthquake can be detected from its seismogram. Its strength is measured either through its intensity or through its magnitude.
- Earthquakes can have very destructive effects on the environment.
- Safety measures must be taken to protect oneself and one's family from the possible dangers that come with the occurrence of an earthquake.

What Have You Learned?

A. Identify what is being described in the sentence. Write your answer on the line before the number.

_____ 1. According to this theory, the earth's lithosphere is made up of plates in constant motion.

_____ 2. This is a graphic record of the occurrence of an earthquake.

_____ 3. This is the point on the earth's crust directly above the focus of an earthquake.

_____ 4. This is a huge, fast-moving wave that results from the occurrence of an earthquake.

_____ 5. This is the layer of the earth found underneath the crust.

_____ 6. These are areas where plates meet.

_____ 7. These are rising and sinking movements in the magma, brought about by the heating up of the mantle.

_____ 8. This is the scale used to describe the magnitude of an earthquake.

_____ 9. These waves are the first to arrive at the seismological station when an earthquake takes place.

_____10. This is the highest intensity of an earthquake based on the Mercalli Scale.

B. Check which of the following items you should bring with you in preparation for an earthquake.

_____	first-aid kit	_____	guns
_____	canned goods	_____	battery-powered radio
_____	candies	_____	flashlight
_____	toys	_____	extra clothes
_____	magazines	_____	water
_____	candles	_____	charcoal for cooking

C. Encircle the letter of the correct answer.

1. During an earthquake, you should _____.

   a. stay wherever you are
   b. run into the building nearest you
   c. go outdoors
   d. stay beside a window

2. Earthquakes can now be predicted with accuracy.

   a. True
   b. False

3. Intensity is affected by such factors as distance of the location from the epicenter and _____.

   a. energy released by the earthquake
   b. presence of bodies of water in the place
   c. nature of surface materials
   d. animal behavior

4. Earthquakes with a magnitude of ____ occur once every 5 to 10 years.

   a. 6.5
   b. 4.5
   c. 7.0
   d. 8.0

5. _____ is a phenomenon that occurs as a result of an earthquake and which leads to a decrease in the strength and stiffness of the soil.

   a. Fire
   b. Tsunami
   c. Liquefaction
   d. Landslide

Compare your answers with those in the *Answer Key* on pages 42 and 43. If you got a score of:

0–10 You should study the whole module again.

11–18 Good! Just review the items that you missed in order to understood them better.

19–27 Very good! You learned a lot from this module. Congratulations!

Answer Key

A. Let's See What You Already Know *(pages 2–4)*

1. **(d)**
2. **(c)**
3. **(a)**
4. **(b)**
5. **(b)**
6. **(c)**
7. **(b)**
8. **(a)**
9. **(d)**
10. **(b)**

B. Lesson 1

Let's Think About This (page 5)

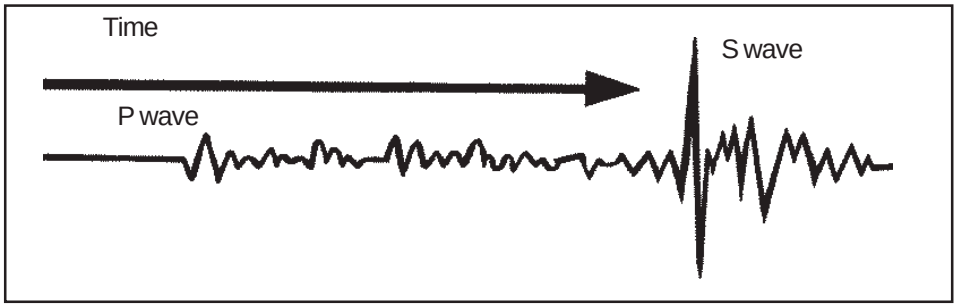
1. The force exerted by the hands on the stick made the stick bend.
2. The stick vibrated right before it broke.

Let's Review (page14)

1. **(b)** Going from the outermost to the innermost parts, the layers of the earth are the crust, mantle and core. The other options include magma and asthenosphere, which are not among the earth's main layers.
2. **(d)** Convection caused by the heating up of the earth's mantle brings rising and sinking movements that lead to plate movements.
3. **(a)** When two plates move away from each other, they form a divergent plate boundary.
4. **(a)** A mountain range is formed along a convergent plate boundary between two continental plates.
5. **(b)** The strongest earthquakes occur in the subduction zone, where one plate slides underneath another plate.

Let's Review (page 19)

1. Body waves travel within the earth, while surface waves travel only on the surface of the earth.

2. 

   The P waves are always the first to arrive and hence be recorded on the seismogram. You will be able to identify P waves based on their appearance. Remember that P waves resemble the movement of a Slinky toy. The left part of the seismogram shows such a type of wave. Time also moves from left to right on the seismogram, hence the wave on the left was the first to arrive. Therefore we can conclude that this is a P wave and that on the right is an S wave.

Let's See What You Have Learned (pages 26–27)

1. **(b)** The two kinds of earthquakes are tectonic and volcanic earthquakes.
2. **(a)** A tectonic earthquake occurs when energy is released as a result of too much stress on a fault caused by movements of rocks.
3. **(d)** A volcanic earthquake is felt whenever a volcano erupts.
4. **(b)** An earthquake occurs as a result of tectonic and volcanic activities.
5. **(c)** The intensity of an earthquake is greater the nearer a locality is to the epicenter.
6. **(d)** Changes in the weather do not indicate that an earthquake is about to occur.
7. **(d)** An earthquake with a magnitude of 7 can cause serious damages to structures and other properties.
8. **(c)** The Philippines lies within the Ring of Fire, which explains the regular occurrence of earthquakes here.

9. **(a)** The more destructive earthquakes occur in Luzon, Masbate and Mindanao because these areas lie along the Philippine Fault.

10. **(c)** The diagram shows one plate **(X)** sliding beneath another plate **(Y)**. **Y** represents a mid-ocean ridge while **X** represents a subduction zone.

C. Lesson 2

Let's Think About This (pages 29)

1. The soft drink rose to the brim of the glass.
2. The shaking action represents an earthquake.
3. (Answers will depend on learners' opinions. The following, however, is the expected answer.) If an earthquake were to occur on an ocean floor, big waves would form and probably reach the shore.

Let's See What You Have Learned (page 36)

1. An earthquake can cause destruction of the environment through fires, tsunamis, landslides and liquefaction. It can cause fear among people and pose possible dangers to their safety and health.
2. (Answers will vary. The following are all possible answers.)

   Before: a. Learn the emergency earthquake plan in your home, community or workplace.

   b. Prepare a battery-powered radio, flashlight, first-aid kit, food, water and other supplies.

   Other possible answers: (a) Learn how to perform first aid; (b) Make sure that all responsible members of the family know how to close the water and gas valves and switch off the electric fuse box; (c) Do not put heavy objects on high shelves; (d) Secure heavy appliances to the floor and anchor heavy furniture to the wall; (e) Devise a plan so that members of the family will be able to stay together during the earthquake; and (f) Practice an earthquake drill for the family and the community regularly.

   During: a. Stay calm and stay where you are.

   b. If you are indoors, stand against the wall nearest the center of the building. You may also stand against a doorway or stay under a desk or some other heavy furniture.

Other possible answers: (a) If you are in a moving vehicle, stop the vehicle and remain inside until the tremor stops; (b) Make sure that every member of your family seeks shelter under a heavy or sturdy furniture; and (c) Direct each member of the family to stay calm and stay away from falling objects.

After: a. Check yourself and other people near you for injuries. Administer first aid if necessary.

b. Check water, gas and electric lines for damages. Close the valves immediately if the lines are damaged.

Other possible answers: (a) Listen to the radio for news updates; (b) Do not flush toilets until sewer lines are checked; (c) Stay out of damaged buildings; (d) Wear boots to protect yourself from shattered glass and other debris; (e) Check for spots in your house that are likely to catch fire; and (f) Do not let the children roam around.

D. What Have You Learned? *(pages 37–38)*

A. 1. theory of plate tectonics
2. seismogram
3. epicenter
4. tsunami
5. mantle
6. plate boundaries
7. convection currents
8. Richter Scale
9. P waves
10. 12 (XII)

B. The following items should be checked: first-aid kit, canned goods, water, battery-powered radio, flashlight, extra clothes. Toys, magazines and candies are not necessities. Guns are very dangerous and have no use at all. Charcoal and candles, on the other hand, might only cause fire if used.

C. 1. **(a)** It is best to stay where you are and seek safety there during an earthquake. Going from one place to another might only endanger your life.

2. **(b)** Up to now, scientists are still looking for ways to determine when and where an earthquake will occur.

3. **(c)** The nature of surface materials will also determine how people in a certain location will experience an earthquake.

4. **(d)** Earthquakes with a magnitude of 8.0 are, fortunately enough, quite rare. They wreak heavy destruction when they strike.

5. **(c)** Liquefaction is what happens when soil becomes less strong and stiff as a result of the occurrence of an earthquake.

Glossary

Asthenosphere Part of the mantle situated below the lithosphere. This zone of weak material exists below a depth of about 100 kilometers and in some regions extends as deep as 700 kilometers.

Earthquake The vibration of the earth's crust produced by the rapid release of energy.

Fault A break in a rock mass along which movement has occurred.

Intensity An indication of the destructive effects of an earthquake on a particular place. Intensity is affected by such factors as distance to the epicenter and the nature of surface materials.

Liquefaction A phenomenon sometimes associated with earthquakes, in which soil and other unconsolidated materials containing abundant water are turned into a fluidlike mass that is not capable of supporting buildings.

Magnitude The total amount of energy released during an earthquake.

Mantle The 2,900-kilometer thick layer of earth located below the crust.

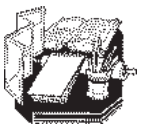
Mercalli Intensity Scale A 12-point scale originally developed to evaluate earthquake intensity based on the amount of damage to various structures.

Mid-ocean ridge A continuous mountainous ridge on the floor of all the major ocean basins and varying in width from 500 to 5,000 kilometers (300 to 3,000 miles).

Richter Scale A scale of earthquake magnitude based on the motion of a seismograph.

Subduction zone A long, narrow zone where one lithospheric plate descends beneath another.

Tsunami A seismic sea wave.



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