Project EASE

(Effective and Alternative Secondary Education)

Plate Tectonics

BUREAU OF SECONDARY EDUCATION
Department of Education
DepED Complex, Meralco Avenue
Pasig City
Plate Tectonics

The progress of the earth sciences and the advancement of technologies associated with the understanding of our planet during the 1940s and 50s have led geologists to develop a new way of looking at the world and how it works. This module covers topics like evidence of plate tectonics and managing effects of natural phenomena associated with plate tectonics.

This module contains the following lessons:

- Lesson 1 - The Structure of the Earth
- Lesson 2 - The Formation of the Continents
- Lesson 3 - Earthquakes
- Lesson 4 - Volcanoes

EXPLORE Your Understanding

As part of initial activities, you will be assessed on your understanding of the structure of the earth, movement of the earth crust, earthquakes and volcanoes gained from elementary science.

Pre-Assessment:

I. Answer each item in your notebook. Do not write anything on this module. Take your time and show me what you know!

1. The crust and upper mantle make up Earth’s __________.
   a. lithosphere  b. asthenosphere  c. core  d. continents

2. What layer of Earth is labeled C?
   a. crust  b. upper mantle  c. lower mantle  d. outer core

3. What layer of Earth’s is labeled A?
   a. outer core  b. upper mantle  c. crust  d. inner core
4. A tectonic plate consists of _____.
   a. the oceanic and continental crust only
   b. the crust and entire mantle
   c. the asthenosphere only
   d. the crust and uppermost mantle

5. Plates of the lithosphere float on the __________.
   a. crust
   b. asthenosphere
   c. outer core
   d. inner core

6. The hypothesis that continents have slowly moved to their current locations is called __________.
   a. continental drift
   b. continental slope
   c. magnetic reversal
   d. convection currents

7. The core of the earth is composed primarily of __________
   a. iron and sulfur
   b. iron and nickel
   c. nickel and silicon
   d. silicon and oxygen

8. A tsunami is a __________
   a. precursor to an earthquake
   b. seismic sea waves
   c. measure of the energy released by an earthquake
   d. a portion of the oceanic crust.

9. The fastest type of seismic waves are ________
   a. P waves
   b. long waves
   c. S waves
   d. surface waves

10. Molten rock which does not reach the surface is called
    a. volcanic ash
    b. magma
    c. basalt
    d. lava
Before you begin with the next part of this module, fill in the first two columns. Fill in the last column after completing the module.

<table>
<thead>
<tr>
<th>Plate Tectonics</th>
<th>What I know</th>
<th>What I want to know</th>
<th>What I learned</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

You have just finished the first phase of this module. As you proceed to the next activities, think of a product output that will enable you to show your understanding of plate tectonics. This product will be presented in the last part of this module which will be assessed based on the following criterion:

Informed decision made on actions that you need to take to manage the effects of natural phenomena or events associated with Plate Tectonics

As you proceed with the rest of the activities, always have this question in your mind, "What does understanding of plate tectonics tell us?"

Better understanding of plate tectonics will be developed as you study the lessons and perform the activities in the FIRM UP phase.
FIRM UP Your Understanding

In this phase, varied learning experiences shall be introduced to help you understand plate tectonics and equip you with skills and knowledge for you to be successful throughout the topic. This involves acquiring scientific knowledge which is about accessing information focusing on plate tectonics.

**Lesson 1. The Structure of the Earth**

Have you ever wondered what is under the ground? You leave your footprints in sand and soil. You touch the soil and play with it. You get some soil samples and identify the substances present in the soil. But nobody has seen beyond the area where humans have conducted mining activities. However, man has invented instruments to get information from the depths of the earth. One such information is on vibration. These vibrations have been recorded and analyzed. Do you know that the earth’s interior is a layered structure composed of core, mantle and crust? Table 1 summarizes the nature of the different layers inside Planet Earth.

**Table 1. Layers of the Earth’s Interior and Their Characteristics**

<table>
<thead>
<tr>
<th>Layer</th>
<th>Characteristics</th>
<th>Chemical composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inner</td>
<td>Very hot Solid Liquid</td>
<td>Iron and Nickel</td>
</tr>
<tr>
<td>Outer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mantle</td>
<td>Upper Layer is partially molten (asthenosphere)</td>
<td>Fe, Mg, Si, O</td>
</tr>
<tr>
<td>Crust</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oceanic</td>
<td>Solid basalt</td>
<td>Mostly O and Si, less amount of P, Al, Mn, Mg, Ca, K, Na</td>
</tr>
<tr>
<td>Continental</td>
<td>Crystalline rocks like granite</td>
<td>Dominated by quartz (SiO₂) and feldspar (metal poor silicates)</td>
</tr>
</tbody>
</table>

Located between the crust and the mantle is the Mohorovicic discontinuity. It separates the crust and the upper mantle. The outermost layer of the Earth is divided into lithosphere and asthenosphere. Lithosphere is rigid, composed of the crust and upper part of the mantle. Asthenosphere is part of the mantle that flows like plastic.

The lithosphere is divided into continental lithosphere and oceanic lithosphere. The former is composed mostly of granite rocks rich in silica and aluminum. The latter is composed of basalt rocks rich in magnesium and aluminum. Fig. 1.1 shows the cross section of what is inside the solid earth.

Fig. 1.1 The inside of the Earth
Activity 1: Model of the Earth Structure

Materials:

- water
- old newspaper
- cooked starch
- basin

Procedure:

1. Cut the old newspaper into tiny pieces.
2. Soak pieces of paper in the basin with water.
3. Using Fig. 1.1 as basis, make a model of the earth’s interior with the use of water-soaked pieces of paper and cooked starch.

Lesson 2. The Formation of the Continents

Get a map or a globe and try to locate the seven continents – Africa, Antarctica, Asia, Australia, Europe, North America and South America. The seven continents are separated by the seven famous world’s oceans. You may be wondering where and how the continents were formed. Let us do activity 2

Activity 2: The Continental Puzzle

Materials:

- globe or map
- pair of scissors
- bond paper
- pencil
- paste

Procedure:

1. Draw the seven continents.
2. Cut out your drawing of the seven continents.
3. Place the continents of similar edges side by side to form a close fit.

Question:

Which continents do you think were neighbors before?
You could have produced a figure similar to Fig. 2.1. This was what Alfred Wegener figured out in 1912.

![Fig. 2.1 Seven continents](image.png)

The two continents further broke up. In 1915, he proposed the Theory of Continental Drift which states that parts of the earth’s crust slowly moved away from each other on top of a liquid core. What are the evidences? The evidences that supported the continental drift theory are the following:

- Fit of the margin of the continents like
  1. Africa and South America
  2. Europe and North America
- Rocks deposits left by glaciers
- Deposits of salts, coal and limestone
- The similarity of rock type and age along the matching coastline
- The continuity of geologic features from continent to continent such as mountain
- The presence of similar fossils found in places he thought were once connected. For instance, fossils of *Mesosaurus* (one of the first marine reptiles, even older than the dinosaurs) and the fossil plant *Glossopteris* were found in both South America

Wegener’s idea left queries in the science community unanswered. An example of these questions is, “How can continents plow through hard, solid ocean floor”? These questions pushed scientists to make more studies which led to the discovery of mid-oceanic ridge. A mid-oceanic ridge is an underwater mountain range. One of this is the famous Mid-Atlantic Ridge, a vast undersea mountain chain in the Atlantic Ocean. It has a gigantic cleft about 32-48 km long and 1.6 km deep. The ridge is offset by fracture zones or rift valleys.
In this cleft, the liquid rock called basaltic magma from the mantle rises up to the floor of the ocean. The hot magma cools down and hardens to form new oceanic crust. The new crust pushed the older rocks away from the ridge. This is called seafloor-spreading theory by Harry Hess (1962) and R. Deitz (1961). What findings support the seafloor spreading theory?

Findings that support Seafloor Spreading theory:

1. Rocks are younger at the mid-ocean ridge.
2. Rocks far from the mid-ocean ridge are older.
3. Sediments are thinner at the ridge.
4. Rocks at the ocean floor are younger than at the continents.

How did they explain the observations listed above? New crusts were added at the ridges of the ocean floor, pushing the old rocks away from the ridges. Also, old crusts were reabsorbed in the ocean trench. A trench is the deepest part of the ocean floor. Just like continental drift theory, the seafloor spreading theory left some gaps. From these two theories, a new theory evolved. This is called **Plate Tectonic Theory**. This theory states that the lithosphere is broken into a number of rigid moving slabs called plates. The plates are either oceanic plates (under the ocean) and continental plates (in the continents) as shown in Fig. 2.2.

![Fig. 2.2 The arrangement of lithosphere and asthenosphere.](image)

The plates move relative to each other above a hotter, deeper, more mobile zone, the asthenosphere. The asthenosphere is kept plasticlike by heat produced from unstable light elements. How do we explain the movement of the lithospheric plates? The very hot substance in the asthenosphere is light and it rises towards the crust where it cools. Cold material is denser and sinks downward. The repeated rising and sinking of materials creates convection currents similar to the event shown in Fig. 2.3.
The convection currents provide horizontal forces on the plates that cause them to move. The moving tectonic plates produce deformations at plate boundaries. Plate boundaries are sections where plates meet and interact. The deformations formed by these tectonic motion result to various landforms on the surface of the earth.

The theory helps explain the formation of the earth’s crust and its movements, collisions, and destruction. It also explains the origin of volcanoes, earthquakes and mountains.

There are three types of plate movements – separation of two plates (divergent), collision of two plates (convergent) and sliding past each other (transform). What is formed at plate boundaries as the plates move relative to each other?

Fig. 2.4 can help you understand plate tectonics. In drawing A, two plates move away from each other. This is a divergent plate boundary. This results to the formation of new crust to widen the sea floor, new ocean basin or a rift valley such as the great African Rift Valley.

In drawing B, an oceanic plate collides with a continental plate. The heavier oceanic plate sinks while the lighter continental plate moves up. These movements form a trench and a volcanic arc. This is a convergent plate boundary.
A transform plate movement is one where two plates slide laterally past each other. (drawing C) However, movement is not smooth due to friction between the rocks of the two plates. Therefore, sometimes the two plates would get ‘stuck’ and lock together. But since the convection currents of the underlying magma are still dragging the plates, much tension and pressure is built up at the transform boundary. When there is sufficient buildup of pressure, rocks in the plates break and get jerked apart. This results in earthquakes.

Earthquakes, volcanoes, oceanic trenches, mountain range formation, and many other geologic phenomenon are deformations at plate boundaries.

Lesson 3. Earthquakes

Why are there Earthquakes? Why do earthquakes happen more in some places than others? To learn more about some kinds of earthquakes, do the following activity.

Activity 3.1 Let’s Make Earthquakes

Materials:
- cardboard box
- metal pan
- uncooked beans or rice
- deck of cards
- dominoes
- building blocks

Procedure:
1. Begin with the cardboard box. Turn it upside down. Build two small houses of cards, one near the edge of the box and one further away.

2. Tap your fingers gently eight to ten times on the box in front of the closest house. Watch the movement of both houses. You should see that the house closest to the tapping receives the most damage, although the walls of both houses will shift position. The different effects are caused by waves of energy sent by the tapping (earthquake). The vibrating energy weakens as it travels.

3. Repeat the experiment, this time with two houses of dominoes. Watch the results.

4. Repeat it once more, this time with block houses. Again, watch the results. The three kinds of structures will show the ability of structures to withstand earthquakes.

5. If desired, the three different housing materials can be built on different surfaces and the experiment repeated. This will show how the various surfaces alter the
effects of the quake's energy waves. After the cardboard box, try an overturned metal pan. Next, invert the pan and fill it with dry rice or beans, and then build the structures on them. What happens in each scenario?

Plate Tectonic Theory can be used to explain the occurrence of an earthquake. The crust has lots of large and small cracks called faults. But you cannot see the faults even if they are very long. The cracks are buried deep underground and the pieces of crust are compressed together very tightly. The powerful forces that compress these crustal pieces also cause them to move very slowly. When two pieces that are next to each other get pushed in different directions, they will stick together for many years. However, these forces pushing on them will break apart cracks and separated cracks move. This sudden shift in the rock shakes all of the rock around it. These vibrations, called **seismic waves**, travel outward in all directions. We call the shaking of the earth as an **earthquake**. The underground location where the rock first broke apart or shifted is called the **focus** of the earthquake. The area above the focus is called **epicenter**.

What are the different ways the crust at the cracks shake? The pieces may move side by side as shown in the figure below or up and down. The movement creates different kinds of waves.

**Primary waves** (or P waves) are the fastest moving waves, traveling at 1 to 5 miles per second (1.6 to 8 kilometers per second). They can pass through solids, liquids and gases easily. As they travel through rock, the waves move tiny rock particles back and forth -- pushing them apart and then back together -- in line with the direction the wave is traveling. These waves typically arrive at the surface as an abrupt thud.

**Secondary waves** (also called shear waves, or S waves) are another type of body wave. They move a little more slowly than P waves, and can only pass through solids. As S waves move, they displace rock particles outward, pushing them perpendicular to the path of the waves. This results in the first period of rolling associated with earthquakes. Unlike P waves, S waves don't move straight through
the earth. They only travel through solid material, and so are stopped at the liquid layer in the Earth's core.

Unlike body waves, surface waves (also known as long waves, or simply L waves) move along the surface of the earth. Surface waves are to blame for most of an earthquake's damage. They move up and down the surface of the earth, rocking the foundations of man-made structures. Surface waves are the slowest moving of all waves, which means they arrive the last. So the most intense shaking usually comes at the end of an earthquake.

The shaking would last for a few seconds to a couple of minutes. Aftershock may follow. There are thousands of earthquakes annually, but many are not felt. What are the dangers of an earthquake?

**The Effect of Ground Shaking**

The first main earthquake hazard (danger) is the effect of ground shaking. Buildings can be damaged by the shaking itself or by the ground beneath them settling to a different level than it was before the earthquake (subsidence).

Buildings can even sink into the ground if soil liquefaction occurs. **Liquefaction** is the mixing of sand or soil and **groundwater** (water underground) during the shaking of a moderate or strong earthquake. When the water and soil are mixed, the ground becomes very soft and acts similar to quicksand. If liquefaction occurs under a building, it may start to lean, tip over, or sink several feet. The ground firms up again after the earthquake has passed and the water has settled back down to its usual place deeper in the ground. Liquefaction is a hazard in areas that have groundwater near the surface and sandy soil.
Buildings can also be damaged by strong surface waves making the ground heave and lurch. Buildings in the path of these surface waves can lean or tip over from all the movement. The ground shaking may also cause landslides, mudslides, and avalanches on steeper hills or mountains, all of which can damage buildings and hurt people.

Photo showing one of Baguio City’s buildings crumbling down due to the earthquake in 1990. Source: http://en.wikipilipinas.org/index.php?title=Image:Baguio quake.jpg

**Ground Displacement**

The second main earthquake hazard is ground displacement (ground movement) along a fault. If a structure (a building, road, etc.) is built across a fault, the ground displacement during an earthquake could seriously damage or rip apart that structure.

The third main hazard is flooding. An earthquake can rupture (break) dams or levees along a river. The water from the river or the reservoir would then flood the area, damaging buildings and maybe sweeping away or drowning people.

Tsunamis and seiches can also cause a great deal of damage. A tsunami is what most people call a tidal wave, but it has nothing to do with the tides on the ocean. It is a huge wave caused by an earthquake under the ocean. Tsunamis can be tens of feet high when they hit the shore and can do enormous damage to the coastline. Seiches are like small tsunamis. They occur on lakes that are shaken by the earthquake and are usually only a few feet high, but they can still flood or knock down houses, and tip over trees.
Waves of the tsunami as they prepare to hit residences in Natori, Miyagi prefecture, Japan. 
Source: http://www.cnbc.com/id/42024887/Scenes_From_the_Japan_Earthquake_and_Tsunami

The oncoming tsunami strikes the coast in Natori City, Miyagi Prefecture, northeastern Japan, March 11, 2011. The biggest earthquake to hit Japan in 140 years struck the northeast coast on Friday, triggering a 10-meter tsunami that swept away everything in its path, including houses, cars and farm buildings on fire.

Caption and Photo source: Reuters.

Fire

The fourth main earthquake hazard is fire. These fires can be started by broken gas lines and power lines, or tipped over wood or coal stoves. They can be a serious problem, especially if the water lines that feed the fire hydrants are broken, too.
Most of the hazards to people come from man-made structures themselves and the shaking they receive from the earthquake. The real dangers to people are being crushed in a collapsing building, drowning in a flood caused by a broken dam or levee, getting buried under a landslide, or being burned in a fire.

Earthquakes may also be caused by volcanic eruptions. People in the vicinity of Mt. Pinatubo felt many quakes prior to the actual eruption.

How do we locate the origin of earthquake? We can use an instrument called a seismograph.

How do we convey information about an earthquake? How do we know how vigorous the shaking of the crust was? Scientists in universities and government agencies like the Philippine Institute of Volcanology and Seismology (PhilVocs) determine the intensity or magnitude of the earthquake. Intensity is the measure of the human reaction to the ground movement and the damage done to the ground surface such as cracks and landslides. Table 3 shows the Rossi-Forel Scale of Earthquake Intensity, used widely in the Philippines.
<table>
<thead>
<tr>
<th>Intensity Scale</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td><strong>Scarcely Perceptible</strong> - Perceptible to people under favorable circumstances. Delicately balanced objects are disturbed slightly. Still Water in containers oscillates slowly.</td>
</tr>
<tr>
<td>II</td>
<td><strong>Slightly Felt</strong> - Felt by few individuals at rest indoors. Hanging objects swing slightly. Still Water in containers oscillates noticeably.</td>
</tr>
<tr>
<td>III</td>
<td><strong>Weak</strong> - Felt by many people indoors especially in upper floors of buildings. Vibration is felt like one passing of a light truck. Dizziness and nausea are experienced by some people. Hanging objects swing moderately. Still water in containers oscillates moderately.</td>
</tr>
<tr>
<td>IV</td>
<td><strong>Moderately Strong</strong> - Felt generally by people indoors and by some people outdoors. Light sleepers are awakened. Vibration is felt like a passing of heavy truck. Hanging objects swing considerably. Dinner, plates, glasses, windows and doors rattle. Floors and walls of wood framed buildings creak. Standing motor cars may rock slightly. Liquids in containers are slightly disturbed. Water in containers oscillate strongly. Rumbling sound may sometimes be heard.</td>
</tr>
<tr>
<td>V</td>
<td><strong>Strong</strong> - Generally felt by most people indoors and outdoors. Many sleeping people are awakened. Some are frighten, some run outdoors. Strong shaking and rocking felt throughout building. Hanging objects swing violently. Dining utensils clatter and clink; some are broken. Small, light and unstable objects may fall or overturn. Liquids spill from filled open containers. Standing vehicles rock noticeably. Shaking of leaves and twigs of trees are noticeable.</td>
</tr>
<tr>
<td>VI</td>
<td><strong>Very Strong</strong> - Many people are frightened; many run outdoors. Some people lose their balance. motorists feel like driving in flat tires. Heavy objects or furniture move or may be shifted. Small church bells may ring. Wall plaster may crack. Very old or poorly built houses and man-made structures are slightly damaged though well-built structures are not affected. Limited rockfalls and rolling boulders occur in hilly to mountainous areas and escarpments. Trees are noticeably shaken.</td>
</tr>
<tr>
<td>VII</td>
<td><strong>Destructive</strong> - Most people are frightened and run outdoors. People find it difficult to stand in upper floors. Heavy objects and furniture overturn or topple. Big church bells may ring. Old or poorly-built structures suffer considerably damage. Some well-built structures are slightly damaged. Some cracks may appear on dikes, fish ponds, road surface, or concrete hollow block walls. Limited liquefaction, lateral spreading and landslides are observed. Trees are shaken strongly. (Liquefaction is a process by which loose saturated sand lose strength during an earthquake and behave like liquid).</td>
</tr>
<tr>
<td>VIII</td>
<td><strong>Very Destructive</strong> - People panicky. People find it difficult to stand even outdoors. Many well-built buildings are considerably damaged. Concrete dikes and foundation of bridges are destroyed by ground settling or toppling. Railway tracks are bent or broken. Tombstones may be displaced, twisted or overturned. Utility posts, towers and monuments mat tilt or topple. Water and...</td>
</tr>
</tbody>
</table>
sewer pipes may be bent, twisted or broken. Liquefaction and lateral spreading cause man-made structure to sink, tilt or topple. Numerous landslides and rockfalls occur in mountainous and hilly areas. Boulders are thrown out from their positions particularly near the epicenter. Fissures and faults rapture may be observed. Trees are violently shaken. Water splash or stop over dikes or banks of rivers.

| IX | Devastating | People are forcibly thrown to ground. Many cry and shake with fear. Most buildings are totally damaged. bridges and elevated concrete structures are toppled or destroyed. Numerous utility posts, towers and monument are tilted, toppled or broken. Water sewer pipes are bent, twisted or broken. Landslides and liquefaction with lateral spreadings and sandboils are widespread. the ground is distorted into undulations. Trees are shaken very violently with some toppled or broken. Boulders are commonly thrown out. River water splashes violently on slopes over dikes and banks. |
| X | Completely Devastating | Practically all man-made structures are destroyed. Massive landslides and liquefaction, large scale subsidence and uplifting of land forms and many ground fissures are observed. Changes in river courses and destructive seiches in large lakes occur. Many trees are toppled, broken and uprooted. |

Source: www.philvocs.dost.gov.ph

Globally, scientists measure magnitude. Magnitude is a measure of the amount of energy released during an earthquake expressed in Richter scale or other magnitude scales. The magnitude is calculated by measuring the amplitude of waves recorded on seismogram, correcting for the distance between the recording instrument and the earthquake epicenter. The magnitude scale is logarithmic. Thus, an earthquake of magnitude 6 produces vibrations with amplitudes 10 times greater than those from a magnitude 5 earthquake and 100 times greater than those from a magnitude 4 earthquake.

In terms of energy, an earthquake of magnitude 6 releases about 30 times more energy than an earthquake of magnitude 5 and about 1000 times more energy than of an earthquake of magnitude 4.

Our country is located in volcanic and earthquake belt. We should adopt precautionary measure for the occurrence of earthquakes. The best protection against earthquakes is to avoid construction in high-risk areas and to use earthquake-resistant construction techniques. Firms, whose business is to build houses and high rise buildings, should have knowledge of the geology of the place. It must make provisions for calamities such as an earthquake. As an individual, what should you do before, during and after the earthquake?
**Before an Earthquake**

1. Secure anything that can be toppled by an earthquake
2. Know how to turn off electricity in your house.
3. Note the nearest accessible exit whenever you enter a building for the first time.
4. Hold fire and earthquake drill at home, in school and offices so everyone will know what to do and where to go.

**During an Earthquake**

1. Keep calm, do not panic.
2. If you are outdoors, move out into an open area away from buildings, which might collapse, and from electric power lines which can snap and electrocute.
3. If caught indoors or in a high-rise building, take cover under tables, desk or bed. You can stay under door frames. Do not use elevator.
4. In school or office, do what you practiced during the earthquake and fire drills.
5. Turn off electricity.

**After an Earthquake**

1. Check electrical devices for any damage before using them again.
2. Inspect house for cracks in its support.
3. Do not go inside collapse structures to get belongings. After shocks may occur anytime.
4. Do not go sightseeing. It is dangerous and you may hamper rescue operations and relief works.
5. Tune in to emergency channels or radio stations for latest information from local authorities on what to do and where to get medical assistance, food and water supplies, temporary shelter and other vital information.
Earthquakes can also trigger landslides. The boxes below may help you with what to do before, during and after a landslide.

<table>
<thead>
<tr>
<th>What to Do Before Landslides</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Inform affected neighbors. Your neighbors may not be aware of potential hazards. Advising them of a potential threat may help save lives. Help neighbors who may need assistance to evacuate.</td>
</tr>
<tr>
<td>• Evacuate. Getting out of the path of a landslide or debris flow is your best protection</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>What to Do During a Landslide</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Quickly move out of the path of the landslide or debris flow.</td>
</tr>
<tr>
<td>• If escape is not possible, curl into a tight ball and protect your head. This position will provide the best protection for your body.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>What to Do After a Landslide</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Stay away from the slide area. There may be danger of additional slides.</td>
</tr>
<tr>
<td>• Check for injured and trapped persons near the slide, without entering the direct slide area. Direct rescuers to their locations.</td>
</tr>
<tr>
<td>• Help neighbors who may require special assistance--infants, seniors and people with disabilities.</td>
</tr>
<tr>
<td>• Listen to local radio or television stations for the latest emergency information.</td>
</tr>
<tr>
<td>• Watch for flooding, which may occur after a landslide or debris flow. Floods sometimes follow landslides because they may be started by the same event.</td>
</tr>
<tr>
<td>• Look for and report broken utility lines to appropriate authorities. Reporting potential hazards will get the utilities turned off as quickly as possible, preventing further hazard and injury.</td>
</tr>
<tr>
<td>• Check the building foundation, chimney and surrounding land for damage. Such damage may help you assess the safety of the area.</td>
</tr>
<tr>
<td>• Replant damaged ground as soon as possible since erosion caused by loss of ground cover can lead to flash flooding.</td>
</tr>
<tr>
<td>• Seek the advice of a geotechnical expert for evaluating landslide hazards or designing corrective techniques to reduce landslide risk.</td>
</tr>
</tbody>
</table>

Lesson 4. Volcanoes

Anyone who has witnessed a volcano erupting needs no further evidence to know that Earth is a dynamic planet. Volcanoes are one of the major mechanisms for creating new crust. They are powerful, breathtaking, and dangerous, and offer scientists an unparalleled glimpse at Earth’s interior. Although the processes that form magma are not well understood, volcanoes — and the igneous rocks they produce — can be studied and explained in the context of plate tectonics. In this
lesson, you will learn the processes that build volcanoes, the factors that influence different eruption types, and the threats volcanoes pose to our surrounding environments.

Volcanism is part of the process that brings material from the deep interior of a planet and spilling it forth on the surface. This may lead to the formation of new crust. How is the new crust formed? It starts from the hot material from below. This hot material called magma comes from two sources. It may be produced when given two lithospheric plates, one slab of crust is forced back down into the deeper regions of the earth as shown in Figure 4.1. This process is called subduction. The slab that is forced back into the earth usually undergoes melting when the edges get to a depth which is hot enough.

![Figure 4.1 Subduction Zone](image)

The magma may also come from the deeper part of the interior of the earth. The hot magma rises and gathers at a reservoir found in a weak portion of the overlying rock called the magma chamber. The magma comes to the surface to form a volcano or island.

A volcano is a place on the earth's surface where molten rock, gases and pyroclastic debris erupt through the earth's crust.

What are the parts of a volcano? Do activity 4.1.

Activity 4.1 Parts of a Volcano

Direction: Use the terms in the word pool to label the part of the volcano.
A volcano has a summit, slope and base. At the summit, this is an opening called vent. A vent may be a crater or caldera. A crater is a funnel-shaped depression at the top of a volcano formed as a result of explosive eruptions. A volcano may have one crater like the Mayon Volcano or more than one crater like the Taal Volcano, which has 47 craters.

Volcanoes erupt in two ways. Some volcanoes erupt through a circular vent above a tube-shaped chimney. Other volcanoes erupt out of a long crack, called fissure, and produce a curtain of lava.
What determines the nature of eruption? It depends on the viscosity of the magma. Viscosity is a measure of a material’s resistance to flow. Higher viscosity materials flow with great difficulty. Viscosity is controlled by temperature of the magma, chemical composition of the magma, and presence of dissolved gases in the magma.

The higher the temperature, the less viscous the magma is. An important substance in the magma is silica ($\text{SiO}_2$). The higher the silica present in the magma, the higher its viscosity. Dissolved gases also affect the mobility of the magma. Gases expand within a magma as they get near the Earth’s surface due to decreasing pressure. The violence of an eruption is related to how easily gases escape from magma. Fluid basaltic lavas generally produce quiet eruptions. Highly viscous lavas (rhyolite or andesite) produce more explosive eruptions. The magma of Philippine volcanoes has high silica content. Thus, our volcanoes erupt violently.

Many Filipinos have witnessed the damage done to Central Luzon when Mt. Pinatubo erupted in 1992. What did the volcano release? One material released was lava. Lava may be thrown into air or may flow out of the opening of the volcano. Lava flows depend on the viscosity of the magma. The following illustrations below show the different lava flows.

**Basaltic flow** is very fluidlike and can travel a great distance forming a thin sheet.

**Andesitic flow** is too viscous to travel far, and tends to break up as it flows.
Volcanic eruptions release pyroclastics such as

- **Rhylolic spire** – in some cases, rhyolitic lava is too viscous to flow at all, and rises out of the vent as a columnar plug.

- **Rhylolic dome** - rhyolitic lava is so viscous that it piles up at a vent as a dome plug.

Volcanic eruptions also release gases such as carbon dioxide, steam, ammonia, and sulfur dioxide.
Let’s look at the different kinds of volcanoes.

**Cinder cone**
- Built from ejected lava (mainly cinder-sized) fragments
- Has steep slope angle
- Is rather small in size
- Frequently occurs in groups
- Famous example is Paricutin in Mexico and Sunset Crater in Arizona

**Shield volcano**
- Has broad, slightly domed-shaped
- Is composed primarily of basaltic lava
- Generally covers large areas
- Is produced by mild eruptions of large volumes of lava
- Examples are Mauna Loa and Kilauea in Hawaii

**Composite cone**
- Most are located adjacent to the Pacific Ocean
- Large, classic-shaped volcano (thousands of ft. high & several miles wide at base)
- Composed of interbedded lava flows and layers of pyroclastic debris
- Examples are Mt. Fujiyama, Mt. St. Helens, Mt. Pinatubo, Mt. Mayon.

Cracks form in the rocks surrounding the magma chambers. Magma from the magma chamber creeps up very slowly into these cracks. These areas are colder than the magma chamber. What will happen to the invading magma? The magma cools down slowly without reaching the surface. The result of this slow process is igneous rock structures called plutons.

Our country has 220 volcanoes and 21 volcanoes are active. Examples are Taal Volcano and Mayon Volcano. There are dangers during volcanic eruptions. Volcanic eruption may occur when there is intense storm. We learned earlier that
volcanic ash fall and release of other pyroclastics are dangers of volcanic eruptions. The box below may help you with what to do in midst of these dangers.

<table>
<thead>
<tr>
<th>What to Do in Case of an Ashfall</th>
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<tbody>
<tr>
<td>• In ashy areas, use dust masks and eye protection. If you don't have a dust mask, use a wet handkerchief.</td>
</tr>
<tr>
<td>• Keep ash out of buildings, machinery, air and water supplies, downspouts, stormdrains, etc.</td>
</tr>
<tr>
<td>• Stay indoors to minimize exposure -- especially if you have respiratory ailments.</td>
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<tr>
<td>• Minimize travel.</td>
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<tr>
<td>• Don't tie up phone line with nonemergency calls.</td>
</tr>
<tr>
<td>• Use your radio for information on the ashfall.</td>
</tr>
<tr>
<td>• Keep the following at home:</td>
</tr>
<tr>
<td>Extra dust masks</td>
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<tr>
<td>Enough nonperishable food for at least three days</td>
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<tr>
<td>Enough drinking water for at least three days (one gallon per person per day)</td>
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<tr>
<td>First aid kit and regular medications</td>
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<tr>
<td>Flashlights with extra batteries</td>
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<tr>
<td>Extra blankets and warm clothing</td>
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<tr>
<td>Cleaning supplies</td>
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<tr>
<th>What to Do During and After an Ashfall</th>
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<tbody>
<tr>
<td>• Close doors, windows and dampers. Place damp towels at door thresholds and other draft sources; tape drafty windows.</td>
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<tr>
<td>• Dampen ash in yard and streets to reduce resuspension.</td>
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<tr>
<td>• Put stoppers in the tops of your drainpipes (at the gutters).</td>
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<tr>
<td>• Protect dust sensitive electronics.</td>
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<tr>
<td>• Since most roofs cannot support more than four inches of wet ash, keep roofs free of thick accumulation. Once ashfall stops, sweep or shovel ash from roofs and gutters. Wear your dust mask and use precaution on ladders and roofs.</td>
</tr>
<tr>
<td>• Remove outdoor clothing before entering a building. Brush, shake and presoak ashy clothing before washing.</td>
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<tr>
<th>What to Do During the Clean Up Period</th>
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<tbody>
<tr>
<td>• Minimize activities that resuspend ash.</td>
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<tr>
<td>• Remove as much ash as you can from frequently used areas. Clean from the top down. Wear a dust mask.</td>
</tr>
<tr>
<td>• Dampen ash to ease removal. Be careful not to wash ash into drainpipes, sewers, storm drains, etc.</td>
</tr>
<tr>
<td>• Use water sparingly. Widespread use of water for clean-up may deplete public water supply.</td>
</tr>
<tr>
<td>• Wet ash can be slippery. Use caution when climbing ladders and roofs.</td>
</tr>
</tbody>
</table>
DEEPEN Your Understanding

Here, you shall be engaged in understanding scientific knowledge which includes the processing and making meanings out of the information. You need to reflect, revisit, revise and rethink your ideas; express your understandings and engage in meaningful self-evaluation; and undergo in-depth exploration of plate tectonics using multiple sources of information and various learning task.

1. Construct a model that will show how the concept on force, motion, energy and matter are involved in plate tectonics. Describe how plate tectonics causes earthquakes, tsunami, mountain formation and volcanic eruptions.

2. Conduct an interview with experts (volcanologist, seismologist, etc.) to understand further those concepts in plate tectonics found to be difficult.

3. Make a background investigation (through literature search, interview or survey) on how safe is one’s immediate community from the occurrences of earthquake, tsunami and/or volcanic eruption.

4. What does understanding of plate tectonics tell us?

Summative Test

A. Directions: Choose the letter of the correct answer. Write it on your notebook. Do not write anything on this module.

1. Which of the following appears to cause movement of Earth's tectonic plates?
   a. convection current below the lithosphere
   b. energy from volcanic activity
   c. magnetic pole reversals
   d. faults in mountain ranges.

Examine the diagram below, and answer the questions that follow.

![Diagram of plate tectonics with labels A, Continental crust, Oceanic crust, and Sea level.](image)
2. In the diagram above, which of the following has formed at A?
   a. an ocean trench  
   b. a mid-ocean ridge  
   c. a transform boundary  
   d. none of the above

3. In the diagram above, which of the following has formed at B?
   a. a folded mountain  
   b. a fault-block mountain  
   c. a volcanic mountain  
   d. none of the above

4. In the diagram above, which type of boundary is A?
   a. a divergent boundary  
   b. a transform boundary  
   c. a strike-slip boundary  
   d. a convergent boundary

5. Which of the following was NOT used as evidence to support the theory of continental drift?
   a. the existence of convection currents  
   b. the similarity of fossils found on continental  
   c. the close fit of continental coastlines  
   d. the matching of glacial grooves on different continent

6. The broad volcanic feature formed by quiet eruptions on the lava flows is called a
   a. shield cone  
   b. composite  
   c. cinder cone  
   d. rift

7. If lava is very thick, the volcano would erupt
   a. silently  
   b. violently  
   c. cannot be determined  
   d. slowly

8. What other major natural disasters do earthquake sometimes cause?
   a. hurricanes  
   b. tsunamis  
   c. tornadoes  
   d. ashfalls

9. Which of the following sequences correctly lists the different arrival of earthquake waves from first to last?
   a. primary waves – secondary waves – surface waves  
   b. secondary waves – surface waves – primary waves  
   c. surface waves – primary waves – secondary waves  
   d. primary waves – surface waves – secondary waves

10. If an earthquake begins while you are in a building, the safest thing for you to do is
    a. lie flat on the floor and cover your head with your hands.  
    b. get under the strongest table, chair or other piece of furniture.  
    c. call home.  
    d. duck near a wall

B. Answer the following briefly.

1. Explain why the Philippines has many volcanoes, experiences lots of earthquakes, and is composed of many islands.
2. Look at the picture below. Make an essay about the picture to explain your concern as criterion to avoid such disaster to happen.

![Image of a disaster scene](image)

TRANSFER Your Understanding

This part will let you transfer your learning in new settings and use this creatively to generate new ideas, view things differently and reengineer processes. You shall be involved in designing, constructing, planning, producing new knowledge and/or inventing products which manifest informed decision making relevant to reducing effects of some plate tectonics-related events.

Activity 1: Self-rescue Evacuation Plan

1. Prepare a self-rescue evacuation plan of the school vicinity. Include in your report the following:
   a. identified objects/places in the classroom and school surroundings which present risk hazards.
   b. measures for eliminating risk hazard caused by certain objects/places in the classroom and school surroundings. (See sample table below)

<table>
<thead>
<tr>
<th>Object/Place</th>
<th>Type of risk which may be caused by the object/place</th>
<th>Security measure Suggestion</th>
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<tbody>
<tr>
<td>1</td>
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</tbody>
</table>
2. Make an evacuation map showing safe paths for passing through during a self-rescue effort; safe places for taking shelter and how to make rescue activities effective.
   a. Make your classroom site plan on the space provided; use symbols to illustrate the objects inside.
   b. Apply red color for places that, in your perception, are very hazardous, green color for safe places, and white for places that are slightly hazardous.
   c. Draw a safe path for passing through during an earthquake, by putting arrows on the site plan that you have made.

3. Do an oral presentation of your findings to your teacher.

4. For extra credit, you may write a concise report to your school principal summarizing the types of hazards in your school and requesting funding to mitigate the hazards. Encourage your principal to provide positive feedback, preferably by addressing one or more of the problems.
Answer Key:

Pre-Assessment

1. a 6. a
2. c 7. b
3. c 8. b
4. a 9. a
5. b 10. b

Summative Test

1. a 6. a
2. a 7. b
3. c 8. a
4. a 9. a
5. a 10. b

References:

Science. Mcdougal Little. 2005

http://www.bse.ph/download/EASE%20MODULES/SCIENCE/SCIENCE%201/Module%201Inside%20the%20solid%20earth.pdf (Accessed on May 16, 2011)
