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Science

Learner's Material
Unit 1

This book was collaboratively developed and reviewed by educators from public and private schools, colleges, and/or universities. We encourage teachers and other education stakeholders to email their feedback, comments, and recommendations to the Department of Education at action@deped.gov.ph.

We value your feedback and recommendations.

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Learner's Material
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UNIT 1

Earth and Space

Unit 1: Earth and Space

Overview

In your Grade 9 Science, part of your lessons was about volcanoes. You have learned about the position of the Philippines in the Ring of Fire and its relationship to the presence of active and inactive volcanoes in our country.

In this quarter, the topics will focus solely on a theory that explains the existence of volcanoes and other geologic features. You have two modules to understand this theory better.

In the first module, you will use some of your science skills such as graphing, measuring, analyzing and interpreting data, and inferring for you to attain the desired outcomes.

What are the outcomes that are expected from you? First, you should identify the types of boundaries created because of lithospheric movements. Secondly, you must relate the movement of Earth's lithosphere to the occurrence of different geologic changes. And finally, you will explain the processes that are taking place along the boundaries.

In the second module, you will perform an activity that will allow you to probe the Earth's interior by analyzing the behavior of seismic waves (Primary and Secondary waves). You will also have an opportunity to simulate one of the properties of the materials present in the mantle.

Lastly, included in the module, and the most important part is the series of activities that will give you an idea about the driving mechanism behind the motion of Earth's lithosphere.

Unit 1
MODULE
1

PLATE TECTONICS

I. Introduction

Our country is blessed with so many land features such as mountains and volcanoes. These features can be sources of different minerals or can be used for agricultural purposes. For example, we have the majestic and world renowned Mayon Volcano. Because of its activity, it produces fertile slopes and plains which are used by the locals to grow their crops. Also, found in the northeastern coast of Luzon, we have the Sierra Madre mountain range which is home to many endemic species of flora and fauna.

Have you ever wondered why our country is endowed with these kind of geologic features? Well, if your answer is YES, then this module will help you find the answer to your question.

In this module, we will study thoroughly the framework that will enable us to understand how and why several features of the Earth continuously change. This theory is what we call “Plate Tectonics.”

This describes the events within the Earth that give rise to mountain ranges, volcanoes, earthquake belts, and other features of the Earth’s surface.

At the end of Module 1, you are expected to answer the key question below:

> What is the relationship among the locations of volcanoes, earthquake epicenters, and mountain ranges?

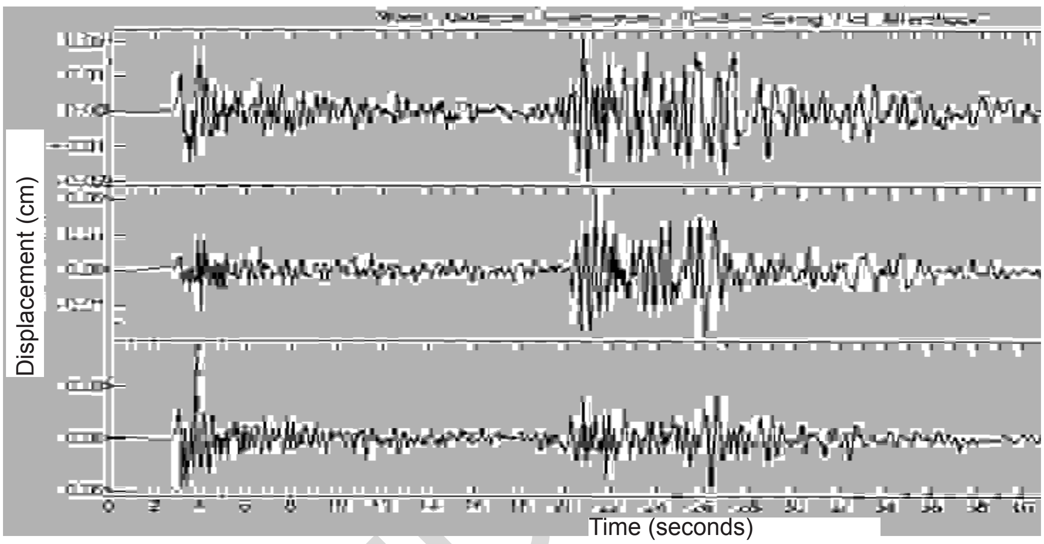
II. Learning Competencies/Objectives

In this module, you should be able to:

1. Describe the distribution of active volcanoes, earthquake epicenters, and major mountain belts.
2. Describe the different types of plate boundaries.
3. Explain the different processes that occur along the plate boundaries.

III. Pre-Assessment

Choose the letter of the correct answer.



For questions 1 and 2, refer to the figure above:

1. You were provided with data showing the arrival time of the P and S-waves recorded from three seismic stations. Which of these can you possibly determine?
   a. the damage at the focus
   b. the distance to the earthquake
   c. the intensity of the earthquake
   d. the location of the epicenter

2. From the seismogram, the distance to the epicenter can be determined by measuring
   a. the arrival time of surface wave
   b. the difference in the arrival times of the P and S-waves
   c. the ratio of the amplitude of the largest P and S-waves
   d. the speed of the surface wave

3. When two tectonic plates collide, the oceanic crust usually subducts beneath the continental crust because it is
   a. denser than continental crust
   b. less dense than continental crust
   c. thicker than continental crust
   d. thinner than continental crust

4. If you visit a place in the Pacific known to be along converging plates, which of these should you **NOT** expect to see?
   a. active volcanoes c. rift valleys
   b. mountain ranges d. volcanic islands

5. You are an oceanographer and want to map the ocean floor on the east coast of the Philippines. As you do your study, you notice that there is a portion in the ocean floor which is relatively much deeper than the rest. What most likely is that deeper part?
   a. linear sea c. rift valley
   b. oceanic ridge d. trench

6. What do you expect to find at a mid-ocean ridge?
   a. relatively young rocks c. thick accumulation of sediments
   b. reverse fault d. very ancient rocks

7. Crustal plate A is moving away from crustal plate B. What is the expected average rate of change in position between A and B?
   a. a few centimeters per year c. a few millimeters per century
   b. a few meters per month d. a few millimeters per day

8. Which plate boundary is formed between the Philippine plate and the Eurasian plate?
   a. convergent c. reverse fault
   b. divergent d. transform fault

9. Which of these is **false** about lithosperic plates:
   a. have the same thickness everywhere
   b. include the crust and upper mantle
   c. thickest in the mountain regions
   d. vary in thickness

10. Which of these is **NOT** true about the Philippine islands?
   a. most are part of the Philippine Mobile Belt, except for Palawan, Mindoro, and Zamboanga
   b. formed because of the convergence of the Philippine plate and the Pacific plate
   c. originated geologically in an oceanic-oceanic convergence
   d. some are products of subduction process

IV. Reading Resources and Instructional Activities

What is Plate Tectonics?

Earth's lithosphere consists of layers, the crust and the upper part of the mantle. This part of the module will focus on the outermost layer which is called crust.

The crust is made of a variety of solid rocks like sedimentary, metamorphic, and igneous. It has an average density of 2.8 g/cm^3 and its thickness ranges from 5 to 50 km. The crust is thickest in a part where a relatively young mountain is present and thinnest along the ocean floor.

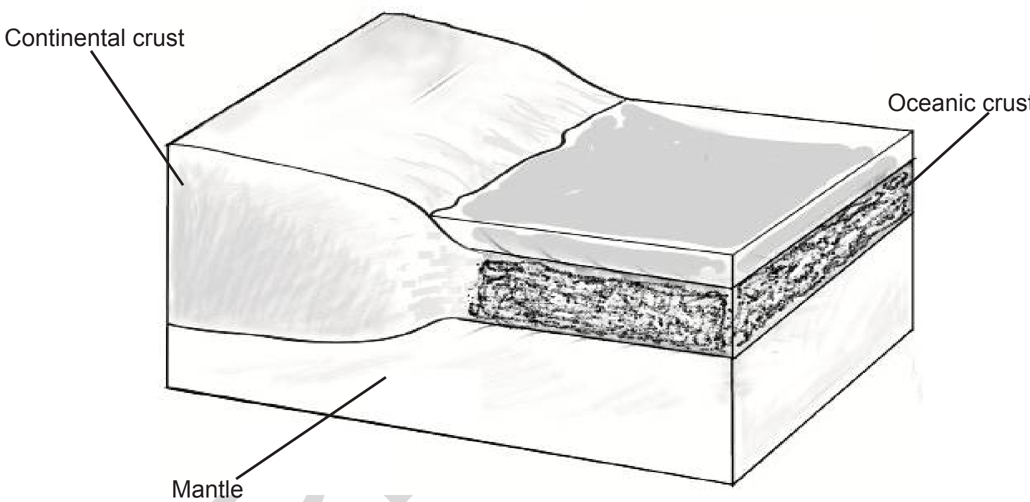
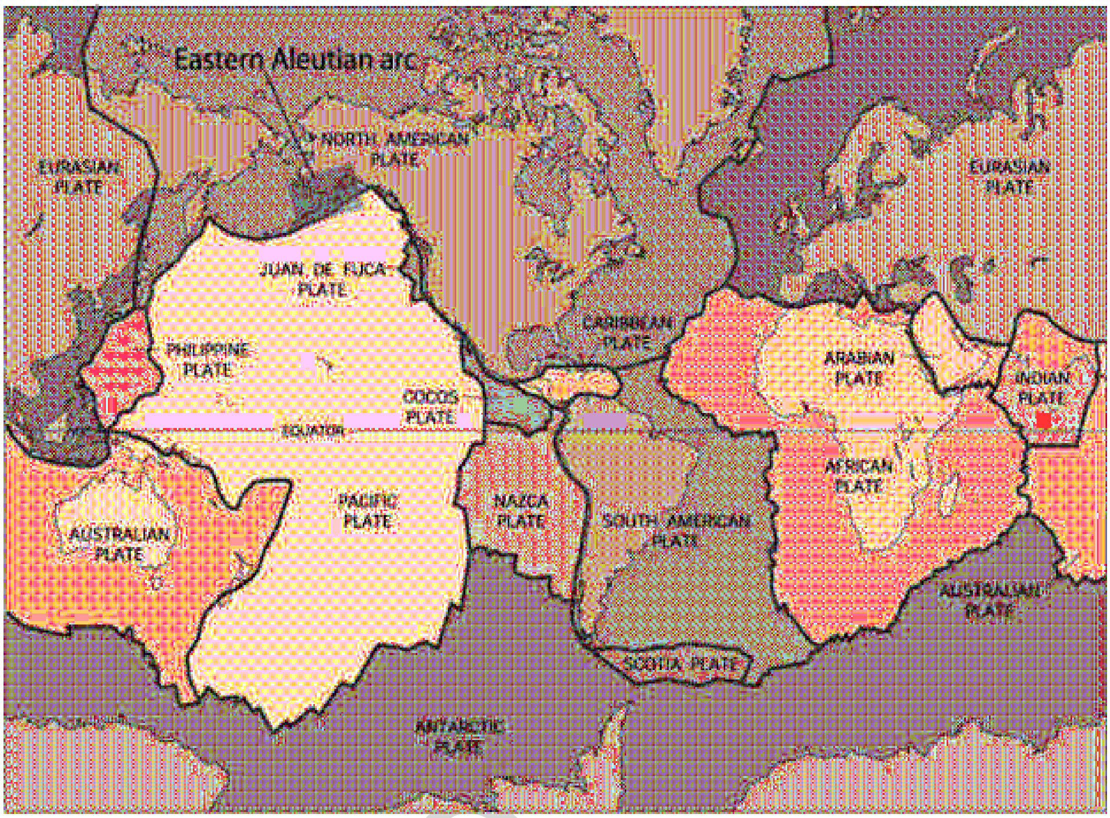


Figure 1. Kinds of crust

You will notice from Figure 1 that there are two kinds of crust: the thicker but less dense continental crust and the oceanic crust which is relatively thinner but denser than continental crust.

According to the plate tectonics model, the entire lithosphere of the Earth is broken into numerous segments called plates (see Figure 2).



http://pubs.usgs.gov
Figure 2. Map of Plate boundaries

As shown in Figure 2, there are seven relatively large plates and a number of smaller ones, including the Philippine plate. The plates move very slowly but constantly, and this movement is called tectonics; thus the theory of moving lithospheric plates is called plate tectonics.

Before we study more about plate tectonics, let's discuss first one of the consequences of moving crustal plates which is crucial in studying plate tectonics: earthquake.

You have learned in your Grade 8 Science that an earthquake releases three types of seismic waves; Primary (P-waves), Secondary (S-waves), and Long surface waves (L-waves). The first two travel into the Earth's interior while the last one on the surface. These waves travel at different velocities; thus, do not arrive at a seismic recording station at the same time. The farther the recording instrument is from the focus, the greater the difference in arrival times of the first P-wave compared to the first S-wave. The difference in the arrival time will tell us the distance of the earthquake's focus from the seismic recording station. However, it does not tell in which direction it came from.

If we have at least three recording stations that can tell how far away from them the earthquake occurred, the epicenter can be determined using the triangulation method. It uses distance information from three seismic stations to locate the earthquake epicenter. On a map, circles are drawn around each seismic station. The radii of the circles are scaled to the estimated distance from the station to the earthquake. The three circles will intersect at one point that locates the earthquake.

The next activity will give you a first-hand experience on how to locate earthquake epicenter.

Activity 1

Find the Center

Objective:

Locate the epicenter of an earthquake using the triangulation method.

Materials:

- hypothetical records of earthquake waves
- Philippine map
- drawing compass and ruler

Procedure:

1. Study the data showing the difference in the arrival time of P-wave and S-wave on three seismic recording stations.

Recording station	Time difference in the arrival time of P-wave and S-wave (seconds)	Distance of epicenter from the station (km)
Batangas	44.8	
Puerto Princesa	32	
Davao	38.4	

2. Compute the distance of the epicenter from each of the stations using this formula:

$$d = \frac{Td}{8\ \text{seconds}} \times 100\ km$$

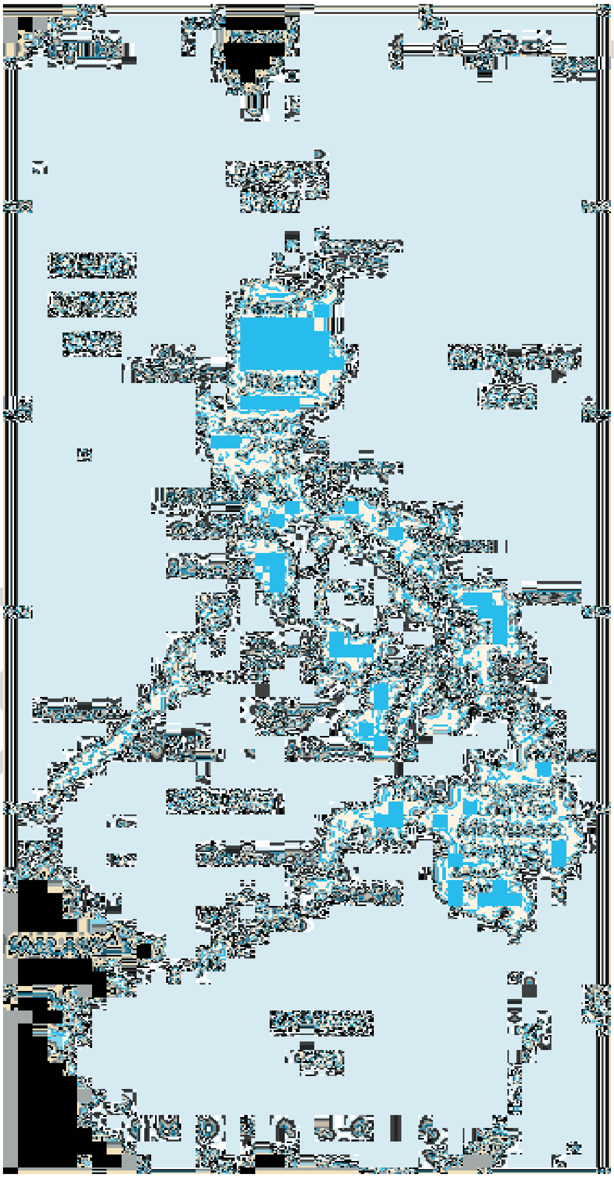
Where: d = distance (km)
Td = time difference in the arrival time of P-wave and S-wave (seconds)

This formula is suited because 8 seconds is the interval between the times of arrival of the P-wave and S-wave at a distance of 100 km.

3. Choose one of the recording stations and measure the computed distance on the map scale (the scale of the map in Figure 3 is 1.5 cm: 200 km). Set your compass for that computed distance.

4. Center your compass on the station you have chosen. Draw a circle.

5. Repeat steps 3 and 4 for the rest of the stations. You should get three circles that intersect or nearly intersect at a point. This intersection is the epicenter.

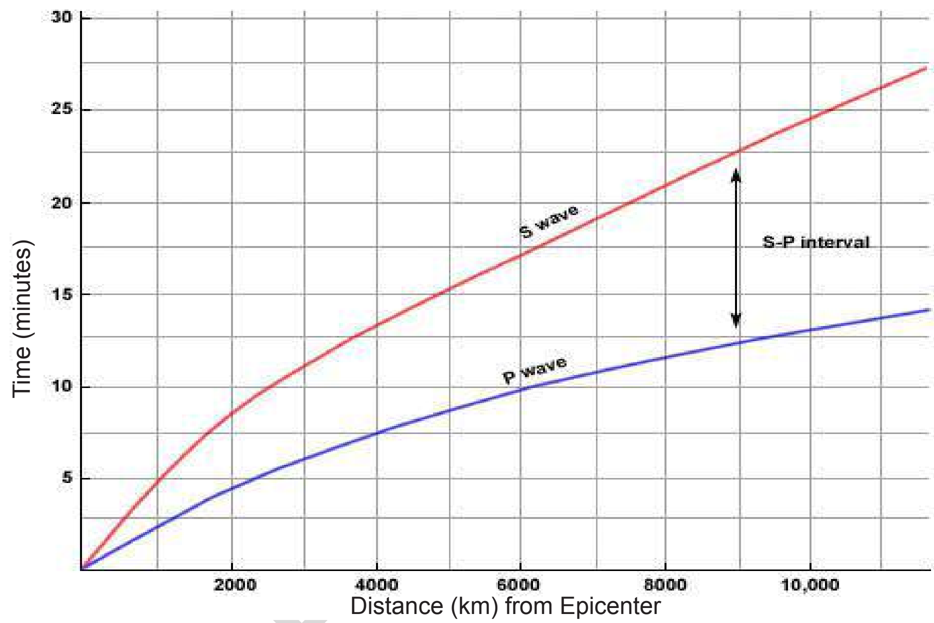


http://earthquake.usgs.gov
Figure 3. Map of the Philippines

Q1. Where is the epicenter of this hypothetical earthquake?

Q2. What difficulty will you encounter if you only have data from two recording stations?

In the previous activity, the hypothetical earthquake happened locally, that is why we use the formula stated in the procedure. But, if the earthquake took place at a far greater distance, seismologists use the distance-time graph similar to the figure below in determining the location of the epicenter.



http://stream2.cma.gov.cn/pub/comet/Environment/TsunamiWarningSystems/comet/tsunami/warningsystem/print.htm

Figure 4. Distance-time graph

The distance-time graph above shows that the S-P interval is about 10 minutes.

Q3. What is the distance of the epicenter from the seismic station?

Q4. What do you think is the importance of determining the epicenter of an earthquake?

Determining the location of earthquake epicenters plays a vital role in laying the foundations of plate tectonics. Let us see how early geologists used the plotted positions of earthquake epicenters throughout the world in conceptualizing crustal movements.

Activity 2

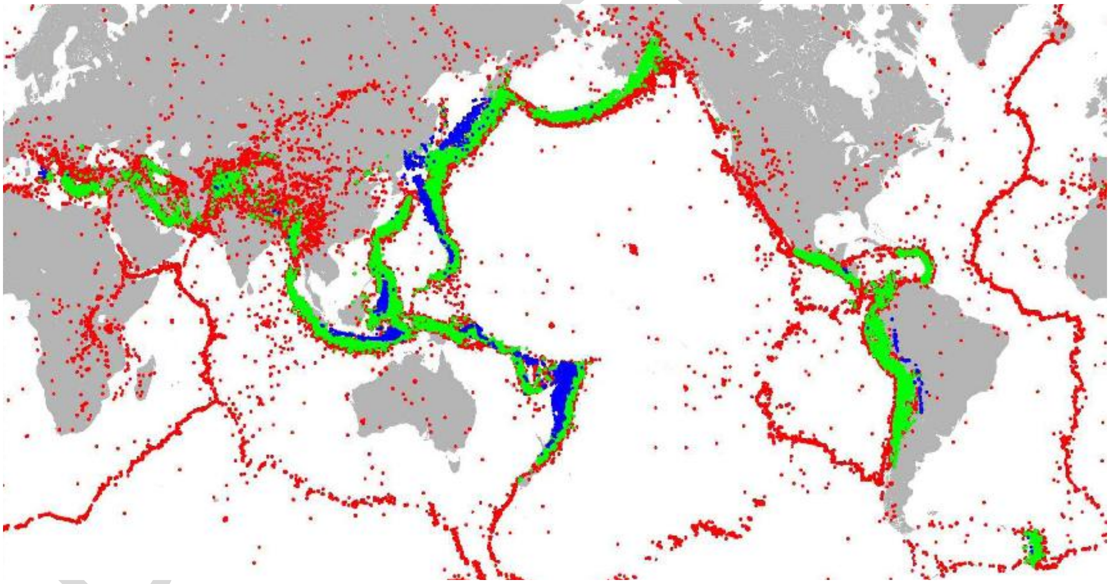
Let's Mark the Boundaries

Objectives:

- Describe the distribution of active volcanoes, earthquake epicenters, and major mountain belts.
- Determine the scientific basis for dividing the Lithospheric plates.

Materials:

- Figure 5: Map of earthquake distribution
- Figure 6: Map of active volcanoes of the world
- Figure 7: Mountain ranges of the world
- 2 pieces plastic sheet used for book cover, same size as a book page
- marking pens (two different colors)



http://marc.fournier.free.free.fr

Figure 5. Map of earthquake distribution (Red, green, and blue dots represent earthquake epicenters)

Procedure:

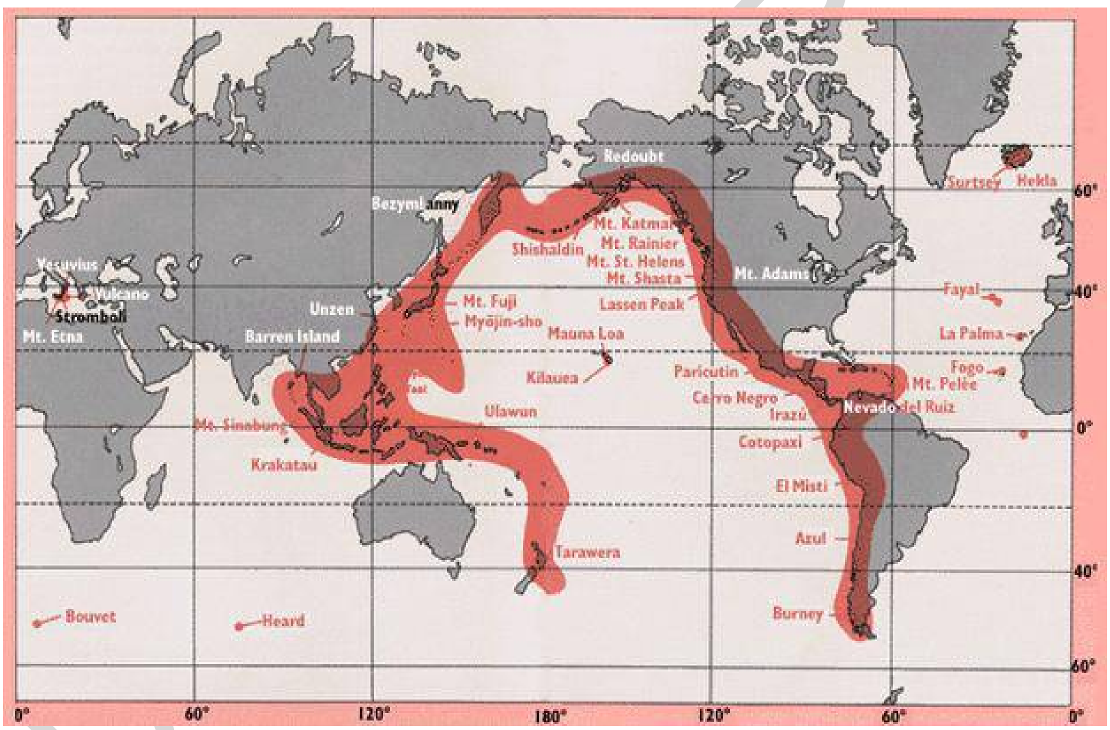
1. Study Figure 5 showing the earthquake distribution around the world. Trace the approximate locations of several earthquake "clusters" using a marking pen on one of the plastic sheets.

Q5. How are earthquakes distributed on the map?

Q6. Where are they located?

Q7. Where are there no earthquakes?

Q8. Why is it important for us to identify areas which are prone to earthquakes?



http://pubs.usgs.gov/gip/volc/fig34.html

Figure 6. Map of active volcanoes (Red areas represent presence of volcanoes)

2. Study the map of active volcanoes in Figure 6.

Q9. How are volcanoes distributed?

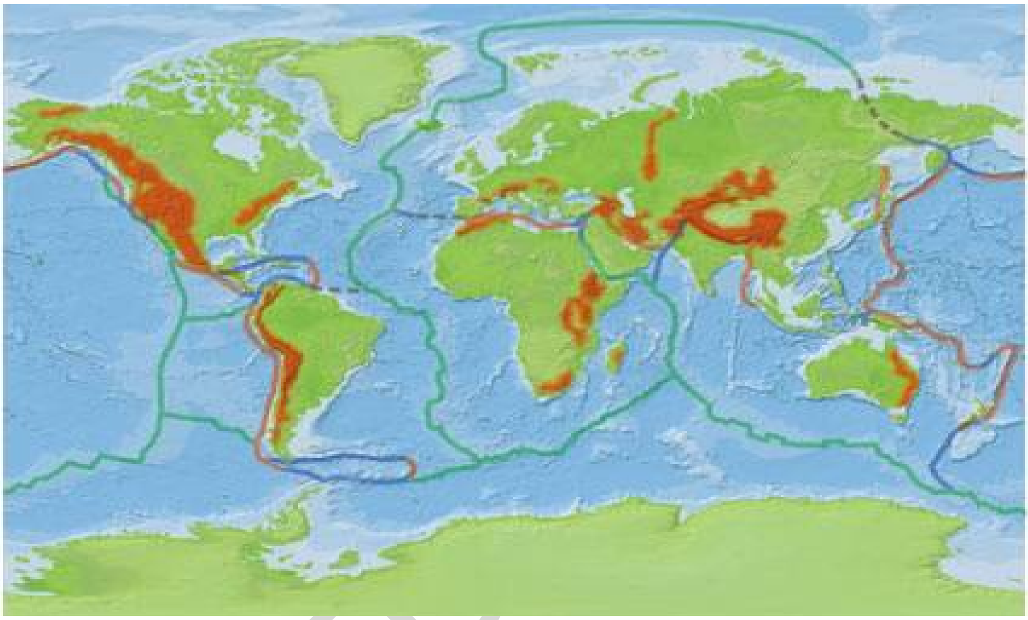
Q10. Where are they located?

Q11. Based on the map, mention a country that is unlikely to experience a volcanic eruption.

3. On the second plastic sheet, sketch the approximate locations of several volcanoes using a marking pen.

4. Place the earthquake plastic sheet over the volcano plastic sheet.

Q12. Compare the location of majority of earthquake epicenters with the location of volcanoes around the world.



http://www.clipart.dk.co.uk/1068/az/Earth/Mountain_ranges

Figure 7. Mountain ranges of the world

5. Study Figure 7, the orange portions indicate mountain ranges of the world.

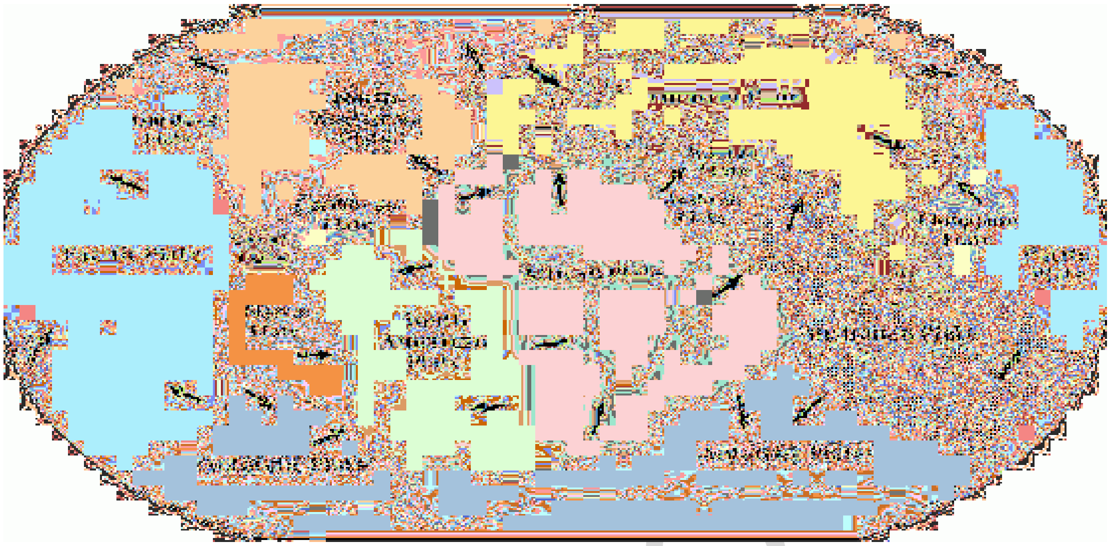
Q13. How will you relate the distribution of mountain ranges with the distribution of earthquake epicenters and volcanoes?

6. Now that you have seen the location of volcanoes, mountain ranges, and majority of earthquake epicenters, study Figure 2 on page 7, Map of Plate boundaries once more.

Q14. What do you think is the basis of scientists in dividing Earth's lithosphere into several plates?

The places on Earth where most of the earthquakes originated or some mountains and volcanoes were formed mark the boundaries of each lithospheric plate. As mentioned earlier, each plate is slowly moving relative to each other, causing geologic events to happen along their boundaries.

Let’s take a look at the relative motion of the crustal plates in the figure below.



https://www.bucknell.edu/majors-and-minors/geology/location/geologic-history-of-central-pennsylvania/plate-tectonics.html

Figure 8. Map showing the relative motion of plates (Arrows indicate the direction of motion)

Types of Plate Boundaries

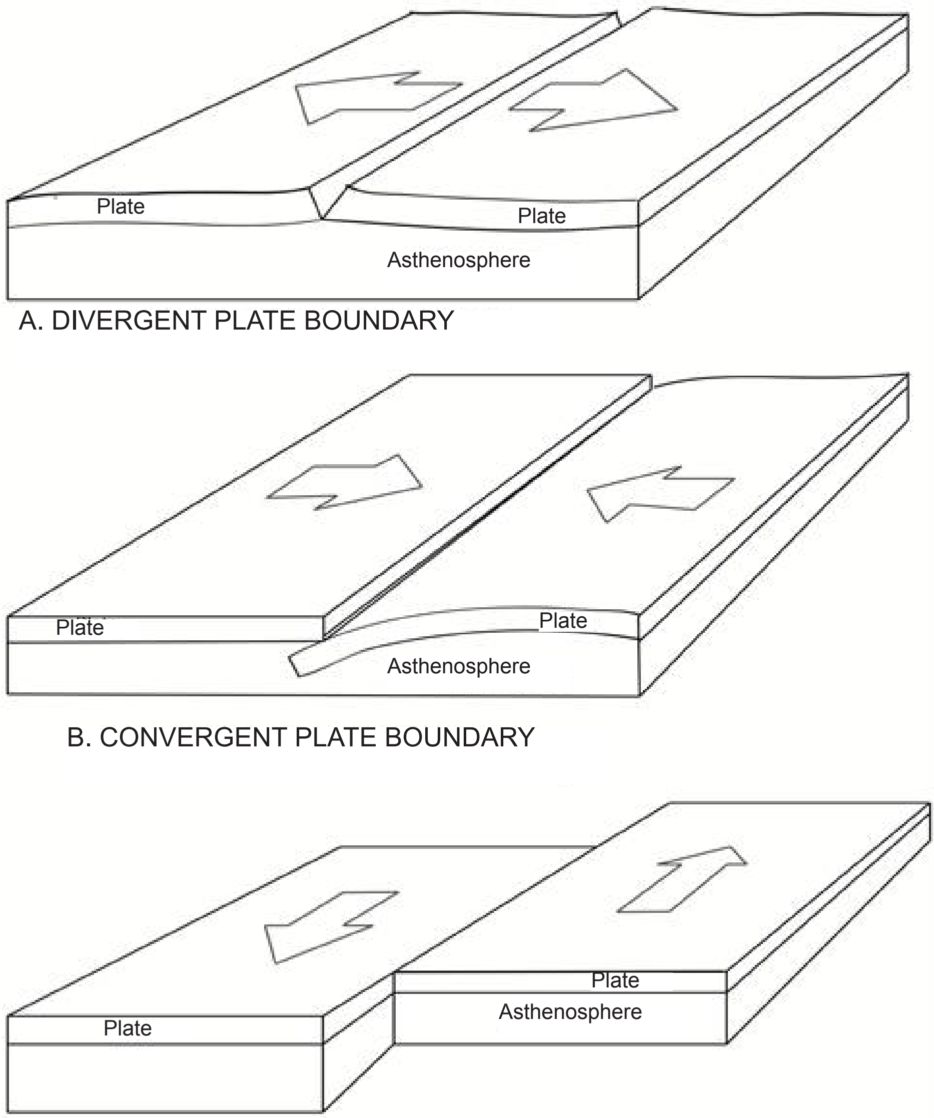
Studying plate boundaries is important because along these boundaries deformation of the lithosphere is happening. These geologic events have a great impact not only on the environment but also on us.

There are three distinct types of plate boundaries, which are differentiated by the type of movement they exhibit.

The first type of plate boundary is termed divergent boundary wherein plates move apart, creating a zone of tension. Can you identify adjacent plates depicting divergent boundary on Figure 8?

Let’s take the case of the Philippine plate and the Eurasian plate. You will notice that the two plates are moving toward each other. This is an example of a zone where plates collide, and this second type of plate boundary is called convergent plate boundary.

The third type is the transform fault boundary where plates slide or grind past each other without diverging or converging. The best example of this plate boundary is the San Andreas fault which is bounded by the North American plate and the Pacific plate.



http://earthsci8.wikispaces.com/
Figure 9. Three types of Plate Boundaries

After learning the different types of plate boundaries, let us now explore the various effects of plate tectonics on Earth's lithosphere.

Activity 3

Head-On Collision

Part A: Converging Continental Plate and Oceanic Plate

Objectives:

- Explain the processes that occur along convergent boundaries.
- Determine the consequences of colliding plates.

Procedure:

1. Study Figure 10 showing a cross-sectional diagram of plates that are converging, and answer the questions that follow.

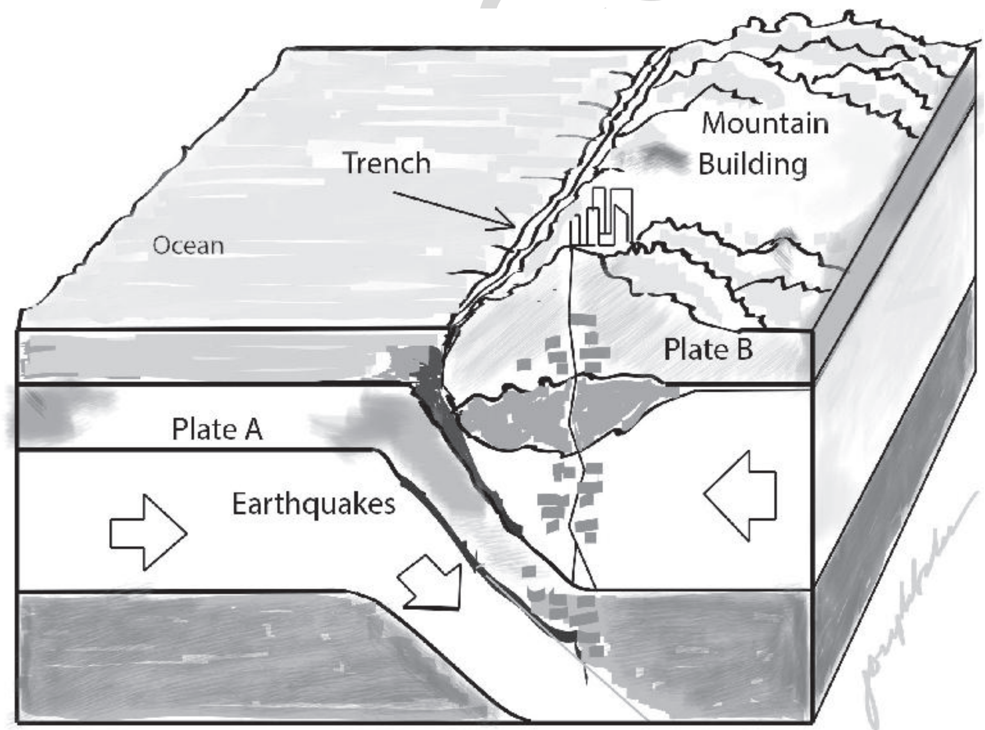


Figure 10. Cross-sectional diagram of converging continental and oceanic plates

Q15. What type of plate is Plate A? What about Plate B? Why do you say so?

Q16. Describe what happens to Plate A as it collides with Plate B? Why?

Q17. What do you think may happen to the leading edge of Plate A as it continues to move downward? Why?

Q18. What do you call this molten material?

Q19. What is formed on top of Plate B?

Q20. As the plates continue to grind against each other, what other geologic event could take place?

Converging Oceanic Crust Leading Plate and Continental Crust Leading Plate

The previous activity depicts what happens during collision of two plates; one has continental edge while the other has an oceanic edge. From the diagram, it is clear that this event gives rise to the formation of a volcanic arc near the edge of a continental leading plate. The reason for this is because the denser oceanic crust (Plate A) undergoes what we call subduction process or the bending of the crust towards the mantle. Since the mantle is hotter than the crust, the tendency is, the subducted crust melt forming magma. Addition of volatile material such as water will cause the magma to become less dense, hence allowing it to rise and reach the crust once again and causing volcanic activities on the continental leading plate.

For the oceanic crust, one important geologic feature is formed, and that is the trench. Also called submarine valleys, ocean trenches are the deepest part of the ocean. One of the deepest is the Philippine trench with a depth of 10 540 meters.

Another subsequent effect of the continuous grinding of plates against each other is the occurrence of earthquakes. The subduction of plate can cause earthquakes at varying depths. Most parts of the world experience occasional shallow earthquakes – where the focus is within 60 km of the Earth's surface. Of the total energy released by earthquakes, 85% comes from shallow earthquakes. Meanwhile, about 12% of energy originates from intermediate earthquakes or those quakes with a focal depth range of 60 to 300 km. Lastly, are the deep earthquakes whose origin is more than 300 km to 700 km below the Earth's surface.

Activity 3

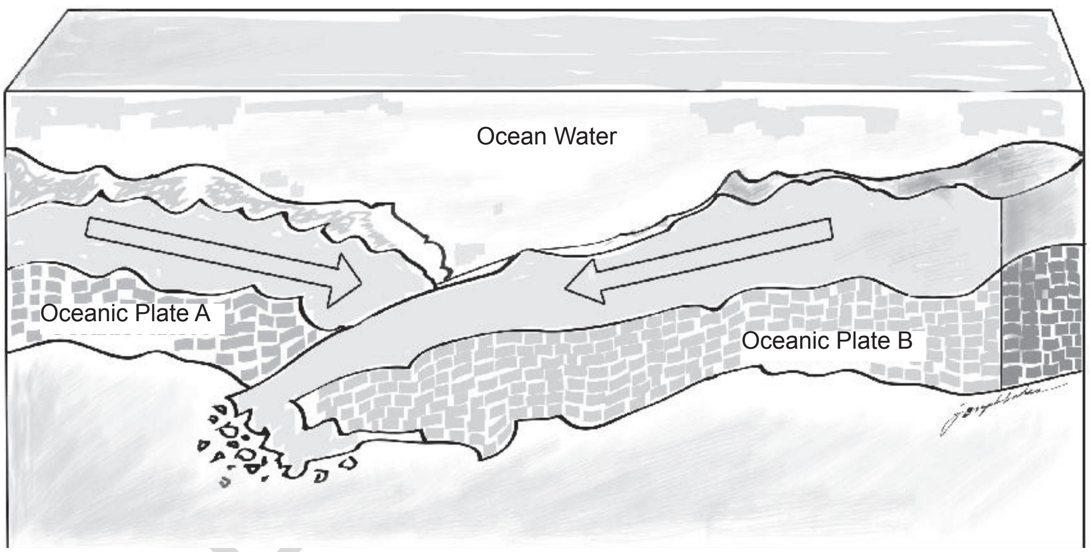
Head-On Collision

Part B: Convergence of Two Oceanic Plates

Procedure:

1. Study Figure 11. It shows a cross-section of two converging oceanic plates.

2. Using your knowledge gained from the previous activity, identify the geologic events or features resulting from this collision.



www.marinebio.net

Figure 11. Cross-sectional diagram of converging oceanic plates

Q21. What are the geologic processes/events that will occur because of this plate movement?

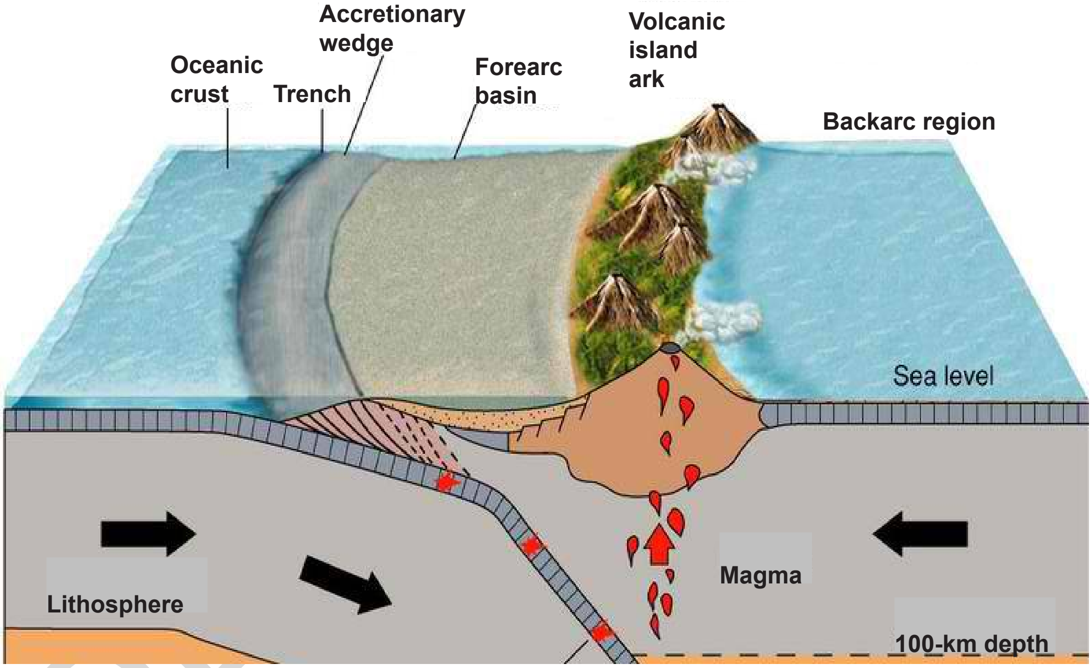
Q22. What geologic features might form at the surface of Plate A?

Q23. If the edge of Plate A suddenly flicks upward, a large amount of water may be displaced. What could be formed at the surface of the ocean?

Convergence of Oceanic Plates

Like the first type of convergent boundaries discussed earlier, converging oceanic plates will cause formation of trenches, and these trenches will become sources of earthquakes. Underwater earthquakes, especially the stronger ones, can generate *tsunamis*. The Japanese term for "harbor wave," *tsunami* is a series of ocean waves with very long wavelengths (typically hundreds of kilometers) caused by large-scale disturbances of the ocean.

The leading edge of the subducted plate will eventually reach the mantle causing it to melt and turn into magma. The molten material will rise to the surface creating a volcanic island arc parallel to the trench. Volcanic island arc is a chain of volcanoes position in an arc shape as seen in figure below.



http://bwbearthenviro2011.wikispaces.com
Figure 12. Formation of a volcanic island arc

Formation of the Philippine Archipelago

Many parts of the Philippines originated from oceanic-oceanic convergence. This resulted from the collision of two oceanic plates, with one of the plates diving under the other.

Majority of the islands in the Philippine archipelago are considered as part of the Philippine Mobile Belt. These islands were formed 65 million years ago at the southern edge of the Philippine Sea Plate and are considered as part of island arcs. Other parts of the Philippines, such as Palawan, Mindoro, and the Zamboanga Peninsula are all highland sections of the Sundaland block of the Eurasian plate (see Figure 13).

Figure 13. Sundaland block of Eurasian Plate which includes Palawan, Mindoro, and Zamboanga

The Philippine Mobile Belt eventually collided with the Sundaland block which explains the presence of trenches, such as the Manila-Negros-Cotabato Trench System, and the Sulu Trench, as shown in Figure 14.

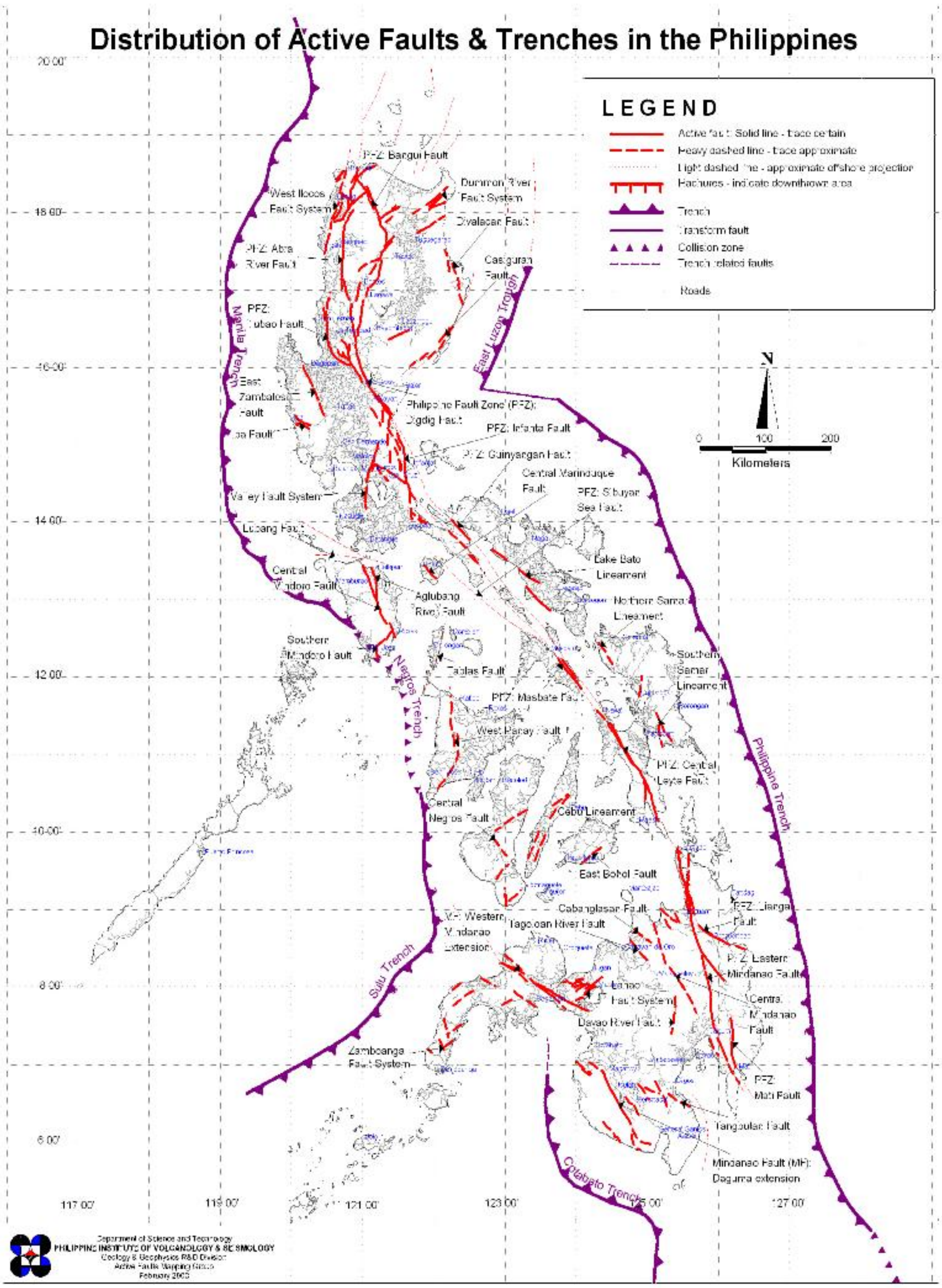
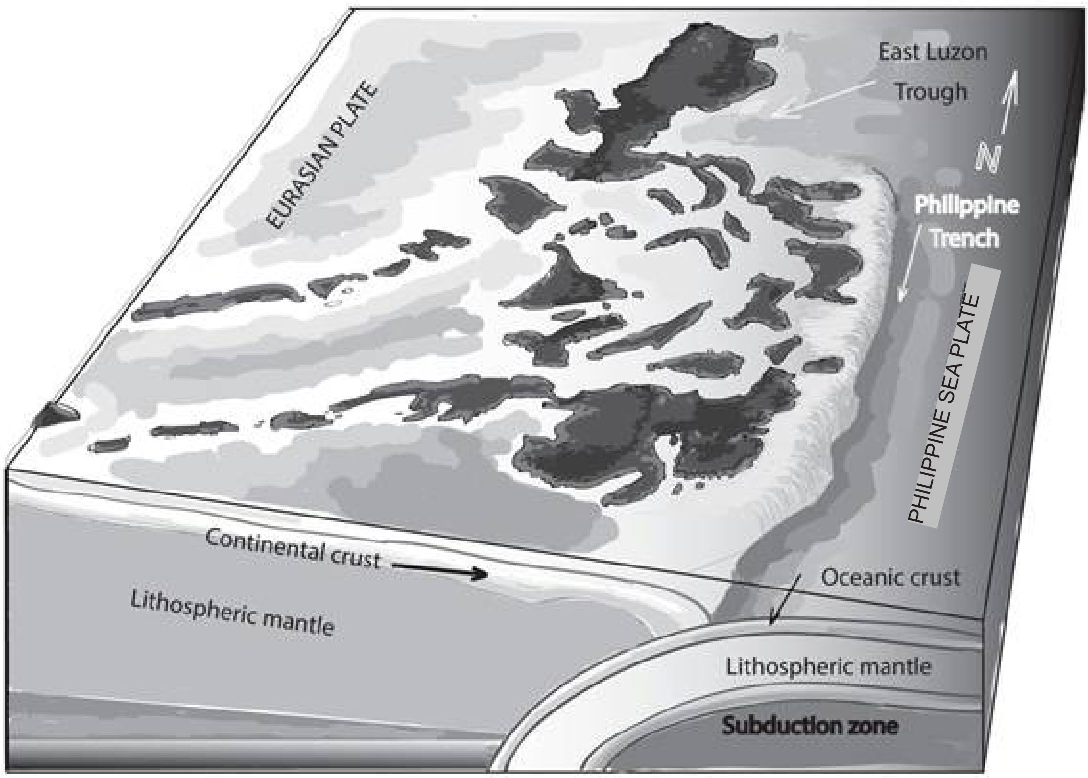


Figure 14. Distribution of Active Faults and Trenches in the Philippines

On the eastern side of the Philippines, trenches like the Philippine Trench and East Luzon Trough are both products of subducting Philippine Sea Plate beneath the archipelago.



http://www.earthobservatory.sg/resources/images-graphics/subduction-zone-beneath-philippines

Figure 15. Subduction of Philippine Sea Plate

Aside from the formation of trenches and troughs, the downward movement of oceanic lithospheres underneath the Philippine Archipelago creates active volcanic chains. For example, the descent of the West Philippine Sea oceanic lithosphere along the Manila Trench created a volcanic chain from Taiwan to Mindoro. Some of the known active volcanoes in this chain are Pinatubo in Central Luzon and Taal in Batangas.

Also, the constant dipping movement of slabs induces frequent moderate to strong earthquakes at various depths, gives rise to mountain ranges and develops the geologic character of the Philippine Archipelago.

Activity 3

Head-On Collision

Part C: Two Continental Plates Converging

Materials:

- modeling clay
- 2 blocks of wood
- paper

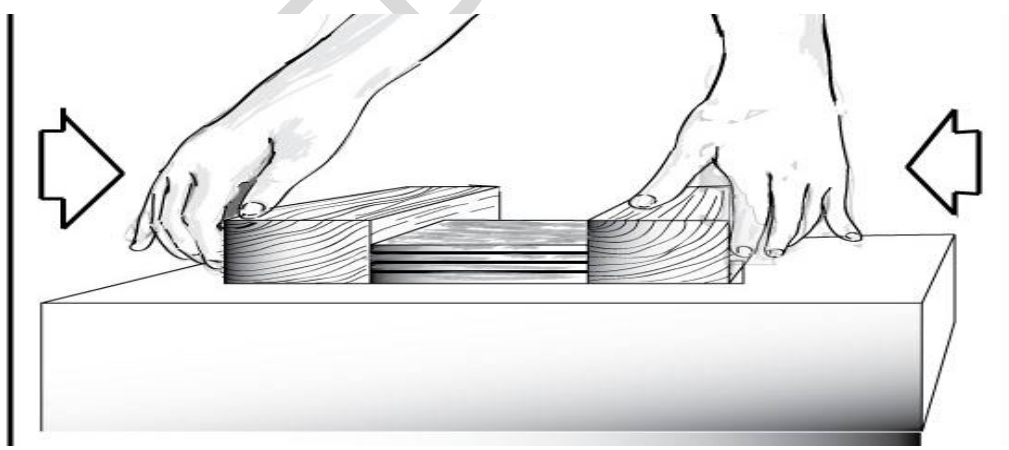
Procedure:

1. On a piece of paper, flatten the modeling clay with the palm of your hand.

2. Cut the clay into four strips; each strip should be 0.5 cm thick, 4 cm wide, and 12 cm long.

3. Put 4 strips one on top of the other.

4. Place a block of wood at each end of the clay strips and slowly push the two blocks together. Observe what happens to the clay.



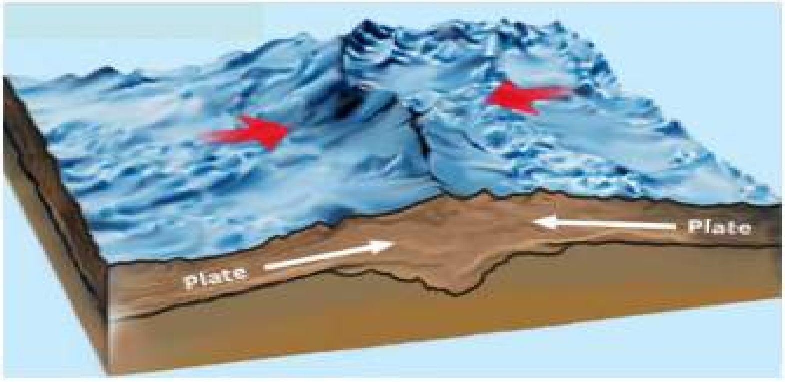
Q24. What happened to the strips of clay as they were pushed from opposite ends?

Q25. If the strips of clay represent the Earth's lithosphere, what do you think is formed in the lithosphere?

Q26. What other geologic event could take place with this type of plate movement aside from your answer in Q25?

Q27. In terms of the consequences on the Earth's lithosphere, how will you differentiate this type of convergent plate boundary with the other two?

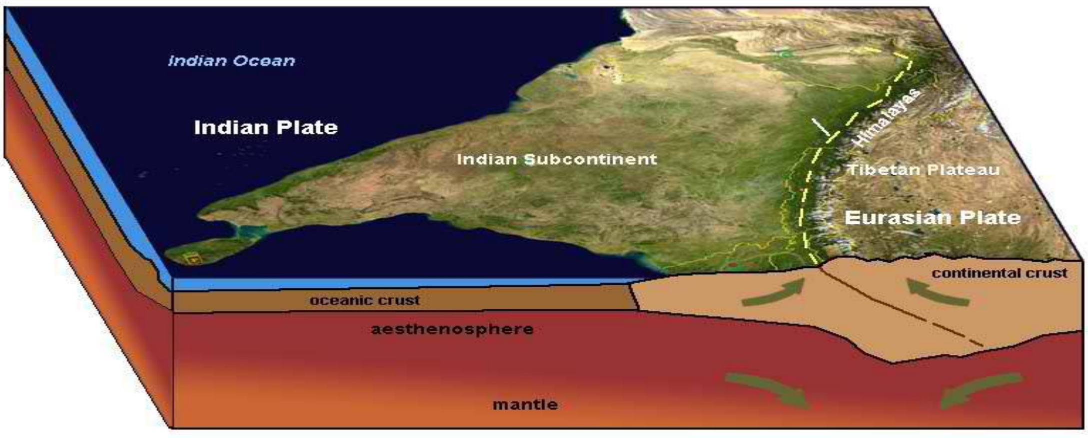
When two continental plates converge, a collision zone is formed. Unlike the other two types of convergent boundaries, subduction ceases for this particular type of convergence. No trench, no volcano, and definitely no island arc are created during this process. Instead, what is created is a large group of tall mountains called mountain range.



http://whybecausescience.com/category/vulcanism/
Figure 16. Formation of mountain range

About 40 to 50 million years ago, two large land masses, India and Eurasia, collided to begin the formation of the most visible product of plate tectonics - the Himalayas. Since subduction is impossible between two colliding continental plates, pressure is released by pushing the crusts upward and forming the Himalayan peaks.

Also, collision of continental plates is associated with shallow earthquake activities.



http://pubs.usgs.gov/
Figure 17. Collision of the Eurasian and Indian plates

After learning the effects of convergent plate boundaries on the Earth's lithosphere, it's time for us to move on to the next type of plate boundary: the divergent plate boundary.

Activity 4

Going Separate Ways

Objectives:

- Explain the processes that occur along divergent boundaries.
- Determine the results of plates that are moving apart.

Materials:

photographs of Rift Valleys and Oceanic Ridges

Procedure:

1. Analyze the photographs of rift valleys (topmost pictures) and oceanic ridges below, and answer the questions that follow.

http://www.adelaidenow.com.au/, http://www.wildjunket.com/, http://www.jnb-birds.com/
Figure 18. Rift valleys and oceanic ridges

Q28. What are common in the four pictures?

Q29. Millions of years ago, the land masses in each picture were once connected. What do you think is happening to the Earth's crust in those pictures?

Q30. If this event continues for millions of years, what do you think will be the effect on the crust?

Q31. Complete the drawing below to illustrate your answer in question number 30.

At present

After millions of years

Divergence of Plates

Formation of rift valleys and oceanic ridges are indications that the crust is spreading or splitting apart. In this case, the plates are forming divergent plate boundaries wherein they tend to move apart. Most divergent boundaries are situated along underwater mountain ranges called oceanic ridges. As the plates separate, new materials from the mantle ooze up to fill the gap. These materials will slowly cool to produce new ocean floor.

The spreading rate at these ridges may vary from 2 to 20 cm per year. Although a very slow process, divergence of plates ensures a continuous supply of new materials from the mantle. The Mid-Atlantic Ocean ridge is an example of spreading center which causes the divergence of the South American plate and the African plate.

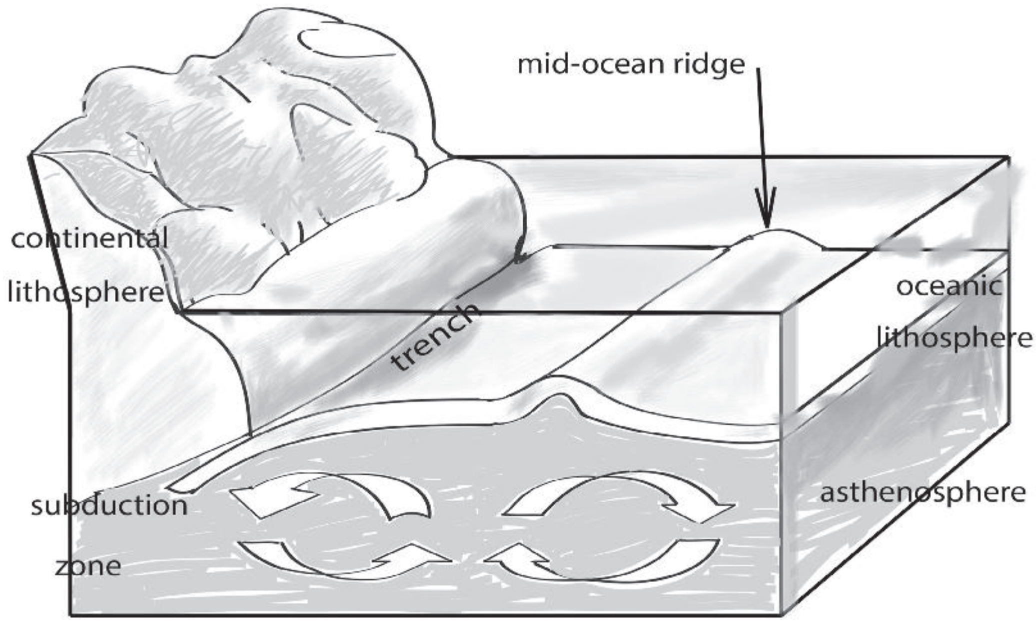
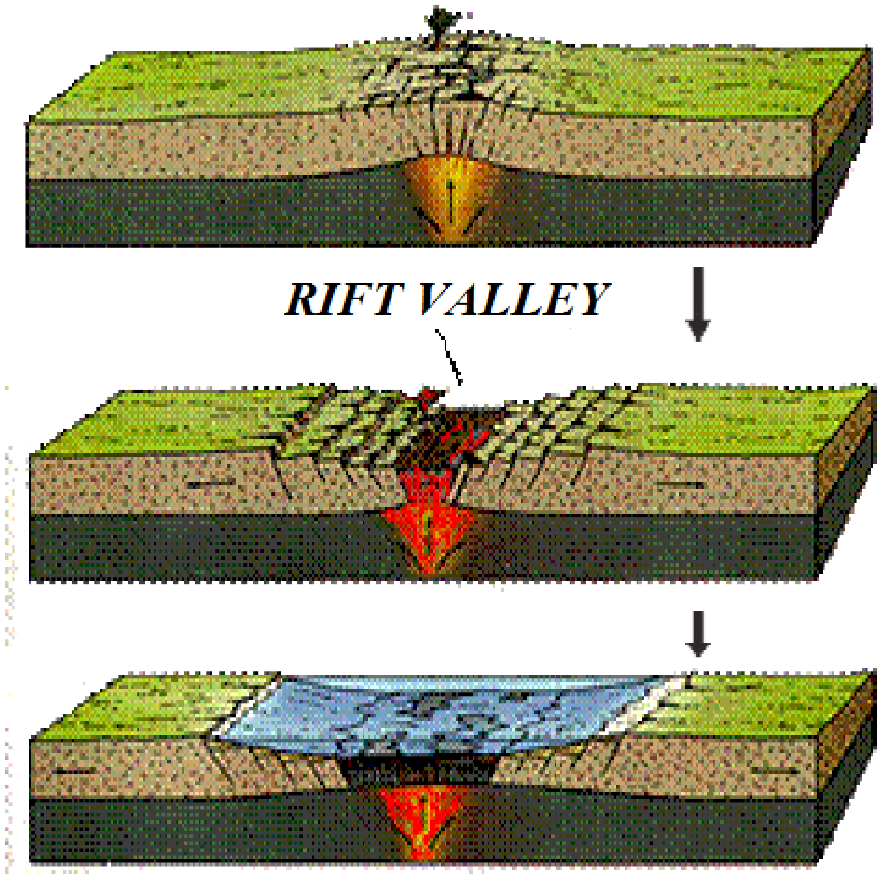


Figure 19. Formation of Mid-Ocean ridge (Diagram by Phyllis Newbill)

When a spreading center develops within a continent, the crust may break into several segments. The breaking leads to the formation of down faulted valleys called rift valleys. It is also associated with the rising of hot materials from the mantle.

The rift valley increases its length and depth as the spreading continues. At this point, the valley develops into a linear sea, similar to the Red Sea today.



http://www.moorlandschool.co.uk/earth/tectonic.htm
Figure 20. Development of a rift valley

In Grade 8, you were introduced to different types of fault such as normal, reverse, and strike-slip. You also learned that faults are fractures in the Earth's crust created by different types of forces acting on the lithosphere.

There is one type of plate boundary that resembles the strike-slip fault. Though much larger, transform fault boundary is similar to strike-slip fault in terms of the relative motion of adjacent slabs of rock.

To find out more about this kind of plate boundary, the next activity will let you simulate the event that could happen out of this boundary.

Activity 5

Slide and Shake

Objective:

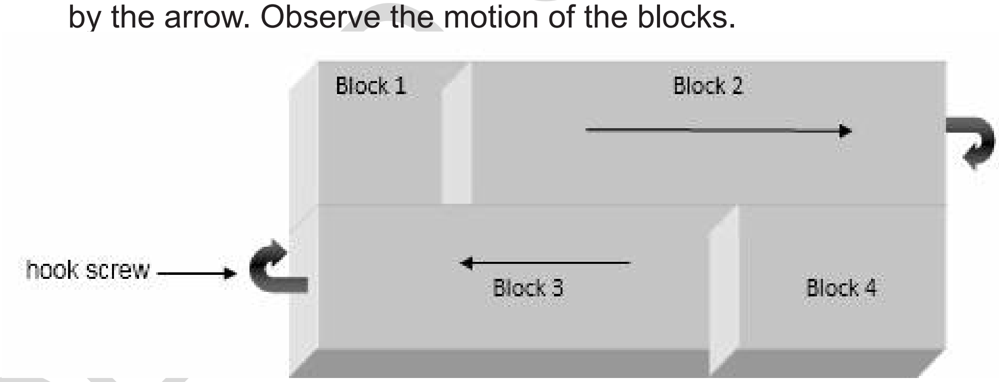
determine the effect of transform-fault boundary on the Earth's crust.

Materials:

- four blocks of wood:
  blocks 1 and 4 measures 5 cm x 5 cm x 10 cm
  while blocks 2 and 3 measures 5 cm x 5 cm x 15 cm
- two hook screws
- sandpaper

Procedure:

1. Attach a hook screw on one end of Blocks 2 and 3.
2. Arrange the blocks as shown in the illustration below.
3. Place sandpaper on the side of the blocks where they all meet.
4. Slowly pull Blocks 2 and 3 on its hook screw to the direction indicated by the arrow. Observe the motion of the blocks.



Q32. Were you able to pull the blocks of wood easily? Why or why not?

Q33. What can you say about the relative motion of blocks 1 and 2? How about blocks 3 and 4?

Q34. How will you describe the interaction between blocks 2 and 3 as you pull each block?

Q35. What is the interaction between blocks 1 and 3? How about between blocks 2 and 4?

Transform Fault Boundaries

If the blocks of wood in Activity 6 were to represent the lithospheric plates, you will notice that there were two sets of divergent plate boundaries (between blocks 1 and 2, and blocks 3 and 4). But since the plates were adjacent to each other, a new type of boundary is manifested and that is the transform fault boundary.

Most transform faults join two segments of a mid-ocean ridge (represented by the gaps between 1 and 2, and between 3 and 4). Remember that the presence of a ridge is an indication of diverging plates, and as the plates diverge between the two segments of the mid-ocean ridge, the adjacent slabs of crust are grinding past each other (blocks 2 and 3, blocks 1 and 3, and blocks 2 and 4).

Although most transform faults are located within the ocean basins, there are a few that cut through the continental crust. An example of this is the San Andreas fault. The immediate concerns about transform fault boundaries are earthquake activities triggered by movements along the fault system.

sanandreasfault.org
Figure 21. San Andreas Fault

It was stated at the beginning of this module that majority of tectonic activities like earthquakes, mountain formations, and volcanic activities happen along or near plate boundaries. But there are some cases wherein activities take place in the middle of a plate.

Let's take the case of the Hawaiian islands. Here, we can find some of the largest and most active volcanoes of the world. If we're going to look at Hawaii, it is situated right in the middle of Pacific plate and not along the boundaries.

What causes the formation of this chain of volcanic islands? The answer lies in an area called hot spot. To better understand this, let's perform the next activity.

Activity 6

Drop It Like It's "Hot Spot"

Objective:

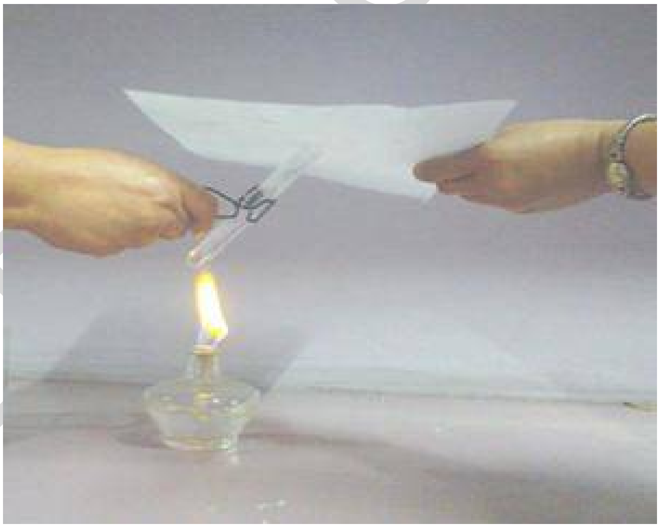
Relate hot spot with plate tectonics

Materials:

- alcohol lamp
- bond paper (2 sheets)
- test tube
- match
- test tube holder
- water

Procedure:

1. Attach one end of the bond paper to the end of another bond paper.
2. Fill 3/4 of the test tube with water and heat it over an alcohol lamp.
3. While waiting for the water to boil, place the paper on top of the test tube. Be sure that the two are in contact.



4. Once the water starts boiling and fumes are coming out, hold the paper in the same position for the next 10 seconds.
5. After 10 seconds, move the bond paper very slowly and horizontally by 10 centimeters. See to it that the paper and test tube are still in contact.
6. Repeat step 5 after another 10 seconds and observe.

Q36. What can you see on the surface of the bond paper?

Q37. Let's say that the paper represents the Earth's crust; what do you think is represented by the water in the test tube?

Q38. What geologic feature do you think will be formed at the surface of the crust?

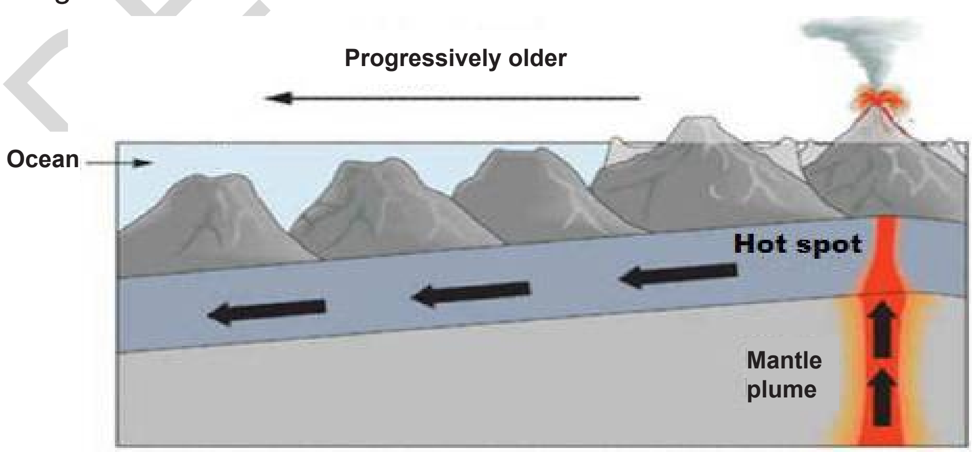
Q39. Which of the features, at the surface of the crust, will be the oldest? the youngest? Label these on your paper.

Q40. Which of the features will be the most active? The least active? Label these on your paper.

Activity 6 gave you an idea how tectonic activities could also happen within a plate and not just along the boundaries.

This idea started when extensive mapping of seafloor volcanoes in the Pacific revealed a chain of volcanic structures extending from the Hawaiian Islands to Midway Islands. When geologists determined the age of each volcanic island through radiometric dating, they noticed that the farther the volcano from Hawaii is, the older and less active it is.

Scientists suggested that there is a source of molten materials from the mantle called mantle plume that formed the volcanic island chains. As the Pacific plate moves, different parts of it will be on top of the mantle plume to receive the molten materials, thus creating the volcanic islands. Continuing plate movement eventually carries the island beyond the hot spot, cutting it off from the magma source, and volcanism ceases. As one island volcano becomes extinct, another develops over the hot spot, and the cycle is repeated. This process of volcano growth and death, over many millions of years, has left a long trail of volcanic islands and seamounts across the Pacific Ocean floor.



http://www.geo.hunter.cuny.edu/
Figure 22. Hot spot forming a chain of volcanoes

Performance Task

At this point, we are quite aware that our country is susceptible to different disasters such as earthquakes, volcanic eruptions, and *tsunamis*. Therefore, it is a must for us to prepare and ensure our safety and survival when these disasters strike.

For this activity, your goal is to help your family prepare for an impending emergency. Your task is to prepare an emergency kit for the whole family. Decide what items should be in your emergency kit and be ready to present it in class.

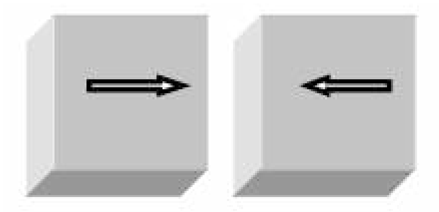
The scoring rubric below will be used in assessing your kit.

	1 pt.	2 pts.	3 pts.	4 pts.
Survival Kit Items	None of the items are necessary for survival during or after a disaster.	A few of the items are clearly necessary for survival during or after a disaster.	At least 8 items are clearly necessary for survival during or after a disaster.	At least 10 items are clearly necessary for survival during or after a disaster.
Labels and Uses	None of the items are labeled properly and there is no reason for including it in the survival kit.	A few of the items are labeled properly and a reason for each item is included on a separate sheet of paper.	At least 8 of the items are labeled properly and a reason for each item is included on a separate sheet of paper.	At least 10 items are labeled properly and a reason for each item is stated on a separate sheet of paper.
	1 pt.	2 pts.	3 pts.	4 pts.
Neatness and Effort exerted	The kit is not organized. It looks like the student threw it together at the last minute without much care.	The kit is somewhat organized and it looks like the student ran out of time or didn't take care of the project.	The kit is done well with some organization and labeling. It appears the student worked hard on it.	The kit is neatly organized and labeled as necessary. Much time and effort were put into creating this project.

V. Summative Assessment

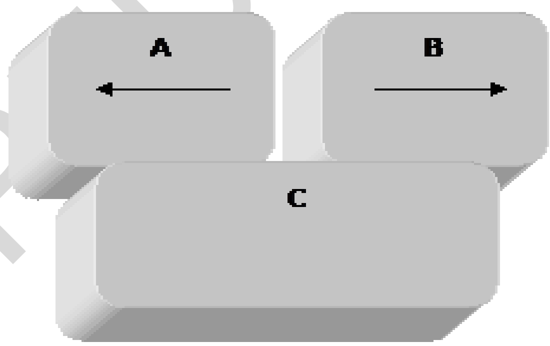
Directions: Answer the following questions;

1. Predict what geologic features could result out of this plate boundary (three possible answers).



2. In a hot spot, Volcano A is on top of the mantle plume, Volcano B is 10 km farther from A while Volcano C is the farthest. What can you infer about the ages of the volcanoes?
   a. Volcano A is older than C c. Volcano B is the youngest
   b. Volcano B is the oldest d. Volcano B is younger than C

3. Right in the middle of an island, you can find a rift valley. What type of plate boundary exists on that island?
   a. convergent b. divergent c. normal fault d. transform fault



4. Plates A and B shows a divergent boundary. If plate C is adjacent to both plates and does not show any relative motion, what type of plate boundary is present between A and C? ___________________

5. What geologic event is most likely to happen at the given type of plate boundary in number 4?
   a. earthquake c. rift valley formation
   b. mountain formation d. volcanic eruption

6. You were asked to locate the epicenter of a recent earthquake. Which correct sequence of events should you follow?

   i. Determine the difference in the arrival time of S and P waves recorded from each of the seismological stations.
   ii. Use the triangulation method to locate the center.
   iii. Obtain data from three different seismological stations.
   iv. Determine the distance of the epicenter from the station.

   a. i, iii, ii, iv   b. iii, i, iv, ii   c. iii, iv, i, ii   d. iv, ii, i, iii

7. What do you expect to find parallel to a trench?
   a. hot spot   b. ocean ridge   c. rift valley   d. volcanic arc

Matching type:
Match column A with columns B and C

A	B	C
Type of Plate Boundary	Relative Motion of the Plates	Geologic Features/ Events Present
8. Divergent	a. Moving away from each other	d. Earthquakes
9. Convergent	b. Moving towards each other	e. Mountains, volcanoes, trenches, and earthquakes
10. Transform fault	c. Sliding past each other	f. Rift valleys, oceanic ridges, and earthquakes

VI. Summary/Synthesis/Feedback

- According to the plate tectonics model, the entire lithosphere of the Earth is broken into numerous segments called plates.
- Each plate is slowly but continuously moving.
- As a result of the motion of the plates, three types of plate boundaries were formed: Divergent, Convergent, and Transform fault boundaries.
- Divergent boundary is formed when plates move apart, creating a zone of tension.
- Convergent boundary is present when two plates collide.
- Transform fault is characterized by plates that are sliding past each other.
- Plate tectonics give rise to several geologic features and events.

Glossary of Terms

Continental volcanic arc	mountains formed in part by igneous activity associated with subduction of oceanic lithosphere beneath a continent
Convergent boundary	a boundary in which two plates move toward each other, causing one of the slabs of the lithosphere to subduct beneath an overriding plate
Crust	the outer portion of the earth
Continental Crust	the thick part of the Earth's crust, not located under the ocean
Oceanic Crust	the thin part of the Earth's crust located under the oceans
Divergent boundary	a region where the crustal plates are moving apart
Earthquake	vibration of Earth due to the rapid release of energy
Fault	a break in a rock along which movement has occurred
Fracture	any break in a rock in which no significant movement has taken place
Geology	the science that studies Earth
Hot spot	a concentration of heat in the mantle capable of creating magma
Magma	a mass of molten rock formed at depth, including dissolved gases and crystals.
Mid-ocean ridge	a continuous mass of land with long width and height on the ocean floor.
Plates	rigid sections of the lithosphere that move as a unit
Plate tectonics	a theory which suggests that Earth's crust is made up of plates that interact in various ways, thus producing earthquakes, mountains, volcanoes, and other geologic features

Primary (P) wave	the first type of seismic wave to be recorded in a seismic station
Rocks	consolidated mixture of minerals
Secondary (S) wave	second type of earthquake wave to be recorded in a seismic station
Seismogram	a record made by a seismograph
Seismograph	a device used to record earthquake waves
Subduction	an event in which a slab of rock thrusts into the mantle
Transform fault boundary	a boundary produced when two plates slide past each other
Trench	a depression in the seafloor produced by subduction process
Volcanic Island arc	a chain of volcanoes that develop parallel to a trench

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sanandreasfault.org

http://www.geo.hunter.cuny.edu/

Suggested time allotment: 15-18 hours

Unit 1
MODULE
2

THE EARTH'S INTERIOR

I. Introduction

Scientists have studied heavenly bodies which are millions of miles away from Earth. Equipped with powerful telescopes and space probes, they were able to reach and examine the solar system and beyond. It seems ironic then, that we haven't, and we couldn't reach the center of our very own planet.

In Module 1, you have learned about the different processes and landforms along plate boundaries that slowly shaped the Earth's surface. In Module 2, you will learn the connection between these processes with the internal structure and mechanisms of our planet.

This module will help you visualize and understand the composition and structure of the Earth's interior. It provides you scientific knowledge that will help you describe the different layers of the Earth as well as understand their characteristics. You will also learn concepts that explain the physical changes that it underwent in the past. This module also consists of activities that will help you develop your critical thinking skills to have a deeper understanding about the planet where you live.

At the end of this module, you will be able to answer the following key questions:

1. How do the structure and composition of the Earth cause geologic activities and physical changes?
2. What are the possible causes of the lithospheric plate movements?
3. What proves the movement of the tectonic plates?

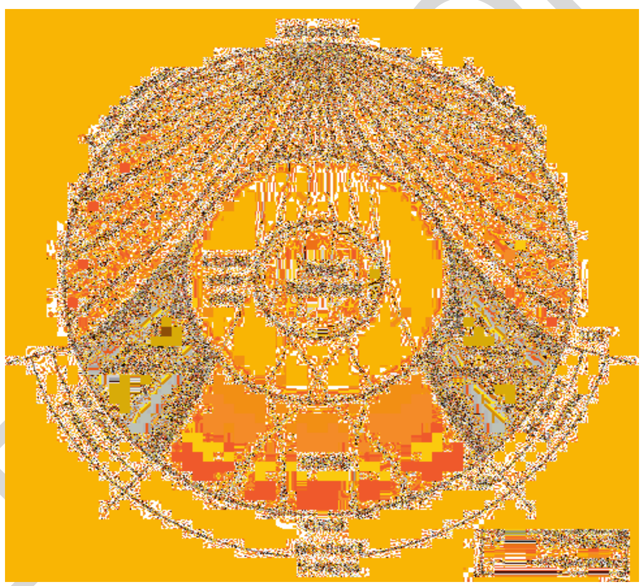
II. Learning Competencies/Objectives

In this module, you should be able to:

1. Describe the internal structure of the Earth.
2. Discuss the possible causes of plate movement.
3. Enumerate the lines of evidence that support plate movement.

III. Pre-Assessment

Directions:
A. Choose the letter of the correct answer.
For questions 1 and 2, refer to the figure below that shows the cross section of the Earth as seismic waves travel through it.



Seismic waves as they travel through the Earth

1. An S-wave shadow zone is formed as seismic waves travel through the Earth's body. Which of the following statements does this S-wave shadow zone indicate?
    a. The inner core is liquid.
    b. The inner core is solid.
    c. The mantle is solid.
    d. The outer core is liquid.

2. Why are there no P-waves or S-waves received in the P-wave shadow zone?
   a. P-waves are absorbed and S-waves are refracted by Earth's outer core.
   b. P-waves are refracted and S-waves are absorbed by Earth's outer core.
   c. Both the P-waves and S-waves are refracted by Earth's outer core.
   d. Both the P-waves and S-waves are absorbed by Earth's outer core.

3. What makes up the lithosphere?
   a. Continental crust
   b. Crust and the upper mantle
   c. Oceanic crust and continental crust
   d. Upper mantle

4. Miners dig into the Earth in search for precious rocks and minerals. In which layer is the deepest explorations made by miners?
   a. Crust
   b. Inner core
   c. Mantle
   d. Outer core

5. How do you compare the densities of the Earth's crust, mantle, and core?
   a. The mantle is less dense than the core but denser than the crust.
   b. The mantle is less dense than both the core and the crust.
   c. The mantle is denser than the core but less dense than the crust.
   d. The mantle is denser than both the core and the crust.

6. The movement of the lithospheric plates is facilitated by a soft, weak and plastic-like layer. Which of the following layers is described in the statement?
   a. Asthenosphere
   b. Atmosphere
   c. Lithosphere
   d. Mantle

7. Alfred Wegener is a German scientist who hypothesized that the Earth was once made up of a single large landmass called Pangaea. Which of the following theories did Wegener propose?
   a. Continental Drift Theory
   b. Continental Shift Theory
   c. Plate Tectonics
   d. Seafloor Spreading Theory

8. If you are a cartographer, what will give you an idea that the continents were once joined?
   a. Ocean depth
   b. Position of the south pole
   c. Shape of the continents
   d. Size of the Atlantic Ocean

9. Which observation was NOT instrumental in formulating the hypothesis of seafloor spreading?
   a. Depth of the ocean
   b. Identifying the location of glacial deposits
   c. Magnetization of the oceanic crust
   d. Thickness of seafloor sediments

10. As a new seafloor is formed at the mid-ocean ridge, the old seafloor farthest from the ridge is destroyed. Which of the stated processes describes how the oceanic crust plunges into the Earth and destroyed at the mantle?
    a. Convection
    b. Construction
    c. Diversion
    d. Subduction

B. Answer briefly the following questions.

1. What are the different layers of the Earth?
2. Why is there a need to study the Earth's layers?
3. What proves the existence of the boundary between the crust and the mantle?
4. What are the characteristics of the asthenosphere?
5. What do the shapes of the continents now tell us about their past?

IV. Reading Resources and Instructional Activities

Studying the Earth's Interior

Scientists tried to explore and study the interior of the Earth. Yet, until today, there are no mechanical probes or actual explorations done to totally discover the deepest region of the Earth.

The Earth is made up of three layers: the crust, the mantle, and the core. The study of these layers is mostly done in the Earth's crust since mechanical probes are impossible due to the tremendous heat and very high pressure underneath the Earth's surface.

In Grade 8, it was mentioned that seismic waves from earthquakes are used to analyze the composition and internal structure of the Earth.

What are seismic waves?

You learned that an earthquake is a vibration of the Earth produced by the rapid release of energy most often because of the slippage along a fault in the Earth's crust. This energy radiates in all directions from the focus in the form of waves called seismic waves, which are recorded in seismographs.

The two main types of seismic waves are body waves and surface waves.

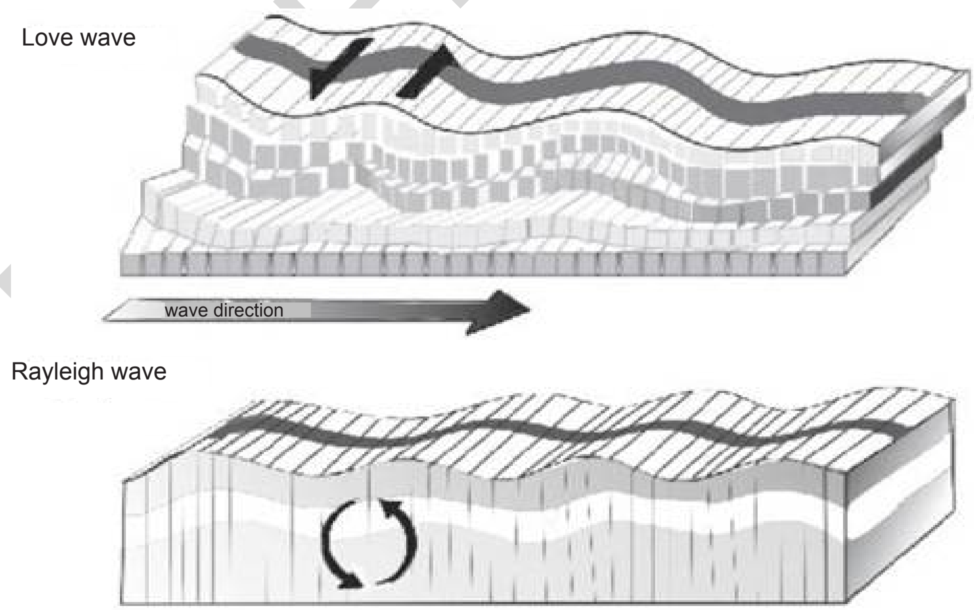


Figure 1. Surface Waves

Surface waves can only travel through the surface of the Earth. They arrive after the main P and S waves and are confined to the outer layers of the Earth. There are two types of surface waves: the Love waves and the Rayleigh waves. Love wave is named after A.E.H. Love, a British mathematician who worked out the mathematical model for this kind of wave in 1911. It is faster than Rayleigh wave and it moves the ground in a side-to-side horizontal motion, like that of a snake's causing the ground to twist. This is why Love waves cause the most damage to structures during an earthquake.

The other kind of surface wave is the Rayleigh wave. It was named after John William Strutt, Lord Rayleigh, who mathematically predicted the existence of this kind of wave in 1885. A Rayleigh wave rolls along the ground just like a wave rolls across a lake or an ocean. Since it rolls, it moves the ground either up and down or side-to-side similar to the direction of the wave's movement. Most of the shaking felt from an earthquake is due to the Rayleigh wave.

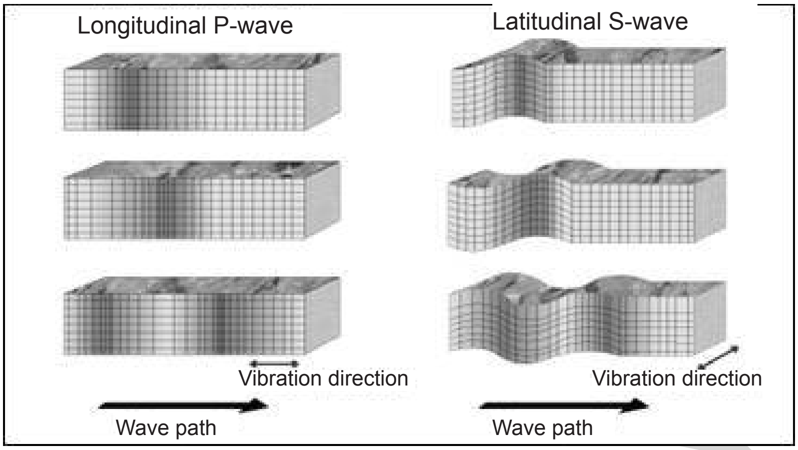
Unlike surface waves, body waves can travel through the Earth's inner layers. With this characteristic of the body waves, they are used by scientists to study the Earth's interior. These waves are of a higher frequency than the surface waves.

The two types of body waves are the P-waves (primary waves) and the S-waves (secondary waves).

What are P and S-waves?

The P-wave (primary wave) is a pulse energy that travels quickly through the Earth and through liquids. The P-wave travels faster than the S-wave. After an earthquake, it reaches a detector first (the reason why it is called primary). The P-waves also called compressional waves, travel by particles vibrating parallel to the direction the wave travel. They force the ground to move backward and forward as they are compressed and expanded. Most importantly, they travel through solids, liquids and gases.

The S-wave (secondary wave or shear wave) is a pulse energy that travels slower than a P-wave through Earth and solids. The S-waves move as shear or transverse waves, and force the ground to sway from side to side, in rolling motion that shakes the ground back and forth perpendicular to the direction of the waves. The idea that the S-waves cannot travel through any liquid medium led seismologists to conclude that the outer core is liquid. Figure 1 shows the vibration directions of P and S-waves.

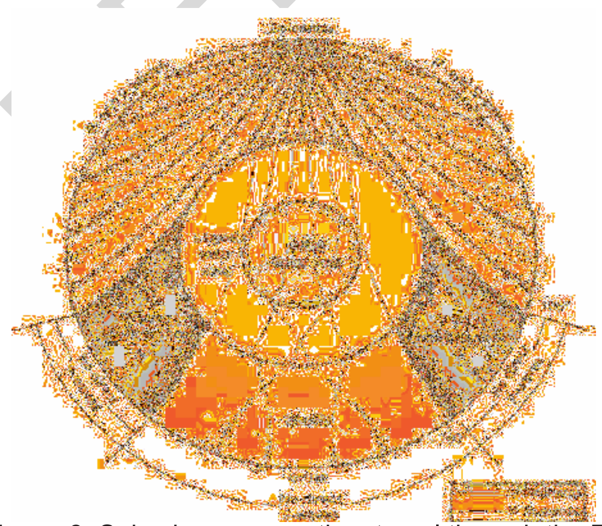


www.furuno.com

Figure 2. Body Waves

Scientists gained information about the Earth's internal structure by studying how seismic waves travel through the Earth. It involves measuring the time it takes for both types of waves to reach seismic wave detecting stations from the epicenter of an earthquake. An epicenter is a point in the Earth's surface directly above the focus. Since P-waves travel faster than S-waves, they're always detected first. The farther away from the epicenter means the longer time interval between the arrival of P and S waves.

In 1909, Yugoslavian seismologist Andrija Mohorovičić (moh-haw-roh-vuh-chich) found out that the velocity of seismic waves changes and increases at a distance of about 50 kilometers below the Earth's surface. This led to the idea that there is a difference in density between the Earth's outermost layer (crust) and the layer that lies below it (mantle). The boundary between these two layers is called Mohorovičić discontinuity in honor of Mohorovičić, and is short termed Moho.



P-waves can travel through liquids while S-waves cannot. During an earthquake, the seismic waves radiate from the focus. Based on figure on the right, the waves bend due to change in density of the medium. As the depth increases, the density also increases.

http://www.cyberphysics.co.uk/topics/earth/geophysics/Seismic%20Waves%20Reading.htm

Figure 3. Seismic waves as they travel through the Earth

P-waves are detected on the other side of the Earth opposite the focus. A shadow zone from 103° to 142° exists from P-waves as shown in Figure 3. Since P-waves are detected until 103°, disappear from 103° to 142°, then reappear again, something inside the Earth must be bending the P-waves. The existence of a shadow zone, according to German seismologist Beno Gutenberg (guː t ə n bɛʁk), could only be explained if the Earth contained a core composed of a material different from that of the mantle causing the bending of the P-waves. To honor him, mantle–core boundary is called Gutenberg discontinuity.

From the epicenter, S-waves are detected until 103°, from that point, S- waves are no longer detected. This observation tells us that the S-waves do not travel all throughout the Earth's body. There is a portion inside the Earth that does not conduct the propagation of S-wave. Hence, knowing the properties and characteristics of S-waves (that it cannot travel through liquids), and with the idea that P-waves are bent to some degree, this portion must be made of liquid, thus the outer core.

In 1936, the innermost layer of the Earth was predicted by Inge Lehmann, a Danish seismologist. He discovered a new region of seismic reflection within the core. So, the Earth has a core within a core. Based on Figure 3 on page 8, we can say that the outer part of the core is liquid based from the production of an S wave shadow and the inner part must be solid with a different density than the rest of the surrounding material.

The size of the inner core was accurately calculated through nuclear underground tests conducted in Nevada. Echoes from seismic waves provided accurate data in determining its size.

Table 1 shows the relative thickness of the different layers of the Earth.

Table 1. Thickness of the Different Layers of the Earth

Layer	Thickness in kilometers
Crust	40
Mantle	2900
Outer core	2200
Inner core	1278

Perform the following activity to test your understanding about seismic waves.

Activity 1

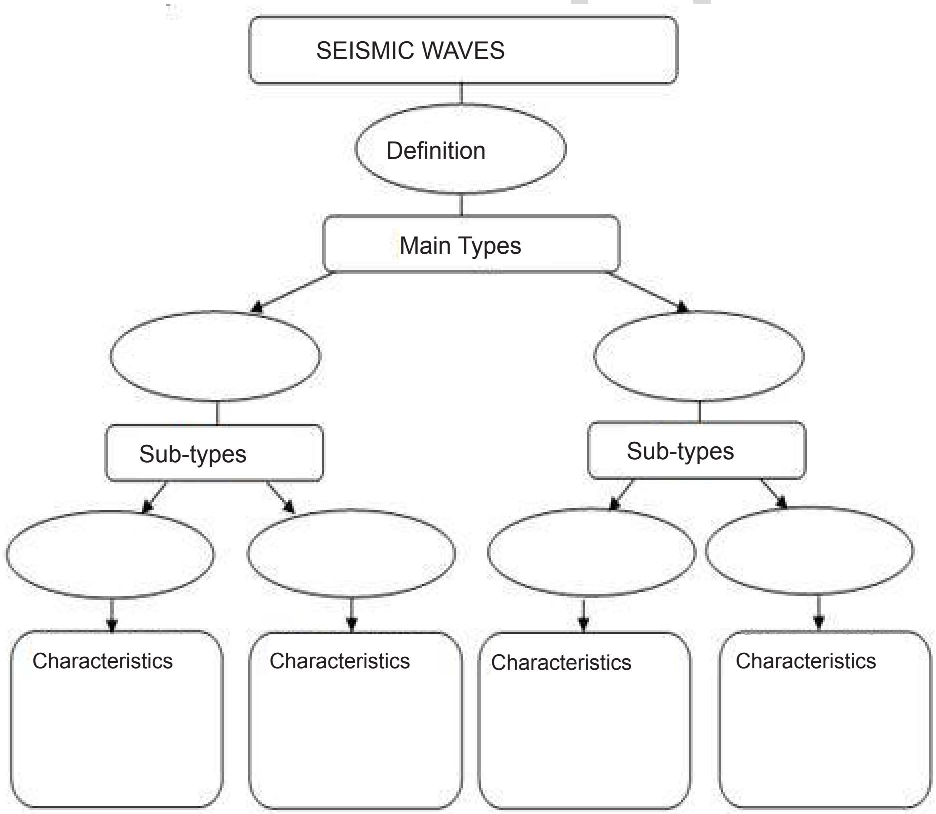
Amazing Waves!

Objectives:

- Define seismic waves scientifically.
- Differentiate the different types of seismic waves.
- Recognize the importance of seismic waves in the study of the Earth's interior.

Procedure:

Using the given organizer, write the necessary information to complete the concept about seismic waves.



Q1. Differentiate surface waves from body waves.

Q2. Which type of waves do you think were useful to seismologists in their study of the Earth's interior? Explain your answer.

The Composition of the Earth's Interior

The Earth's composition tells a story about itself. It gives us clues to its past and proofs about the gradual and slow changes that it has undergone for over 4.6 billion years.

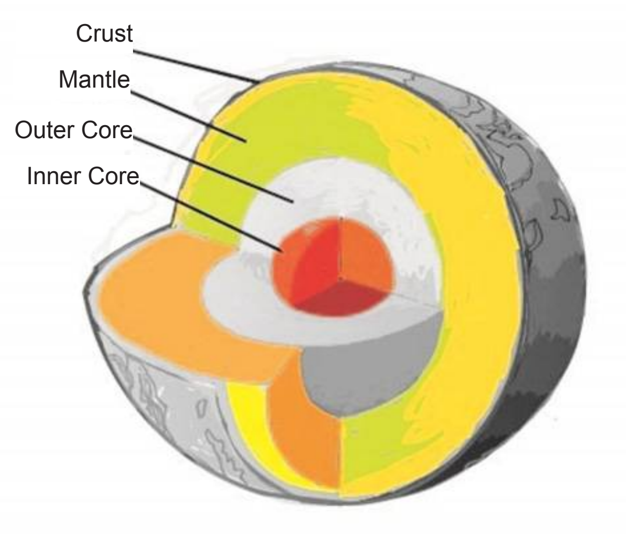
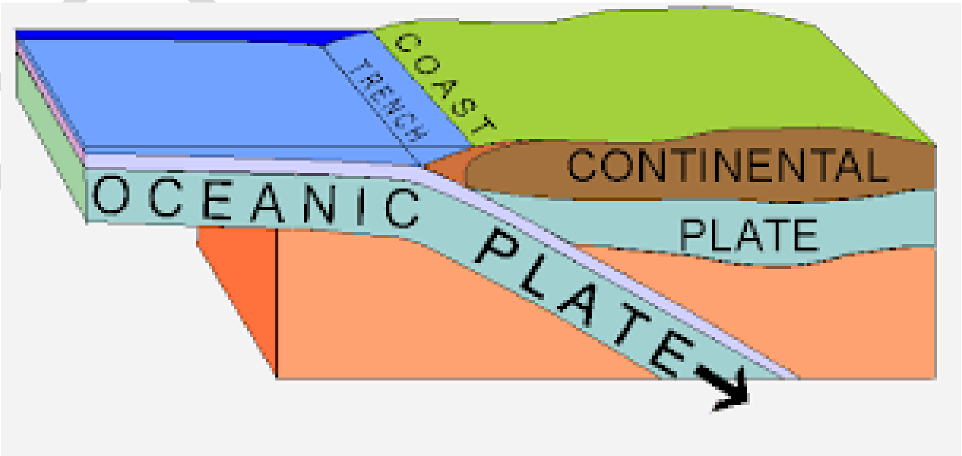


Figure 4. Earth's Cross Section

The Crust

The crust is the thinnest and the outermost layer of the Earth that extends from the surface to about 32 kilometers below. Underneath some mountains, the crust's thickness extends to 72 kilometers. The Earth's crust, as gleaned from Figure 5 on page 12, is subdivided into two regions: the continental crust and the oceanic crust.



https://mrb-science.wikispaces.com/Plate+Tectonics
Figure 5. The Continental and the Oceanic Crust

The continental crust is mainly made up of silicon, oxygen, aluminum, calcium, sodium, and potassium. The thickness of the continental crust is mostly 35-40 kilometers. Continental crust, found under land masses, is made of less dense rocks such as granite.

The oceanic crust is around 7-10 kilometers thick which its average thickness is 8 kilometers. It is found under the ocean floor and is made of dense rocks such as basalt. The oceanic crust is heavier than the continental crust.

The crust consists of two layers. The upper layer is composed of granite and is only found in the continental crust. Below the granite is a layer made mainly of basalt. This is found on both under the continents and the oceans.

Table 2 shows the different elements that compose the Earth's crust.

Table 2. Elements in the Earth's crust

Element	Percentage
Oxygen	46.60
Silicon	27.72
Aluminum	8.13
Iron	5.00
Calcium	3.63
Sodium	2.83
Potassium	2.59
Magnesium	2.09
Titanium	0.40
Hydrogen	0.14

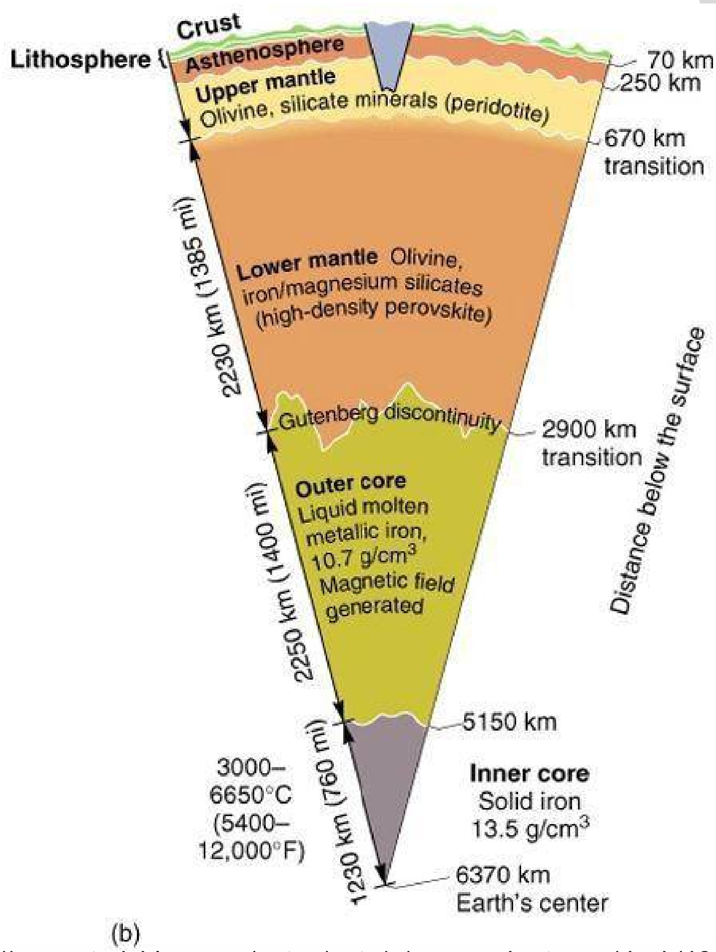
The Mantle

Beneath the crust is the mantle, which extends to about 2900 kilometers from the Earth's surface. It makes up about 80% of the Earth's total volume and about 68% of its total mass. The mantle is mainly made up of silicate rocks, and contrary to common belief, is solid, since both S-waves and P-waves pass through it.

The attempt to study the Earth's mantle extended as far as studying the rocks from volcanoes, simply because they were formed in the mantle. Scientists also studied rocks from the ocean floor. They have determined that the mantle is mostly made of the elements silicon, oxygen, iron and magnesium. The lower part of the mantle consists of more iron than the upper part. This explains that the lower mantle is denser than the upper portion. The temperature and the pressure increase with depth. The high temperature and pressure in the mantle allows the solid rock to flow slowly.

The crust and the uppermost part of the mantle form a relatively cool, outermost rigid shell called lithosphere and is about 50 to 100 kilometers thick. These lithospheric plates move relative to each other.

Beneath the lithosphere lies the soft, weak layer known as the asthenosphere, made of hot molten material. Its temperature is about 300 – 800°C. The upper 150 kilometers of the asthenosphere has a temperature enough to facilitate a small amount of melting, and make it capable to flow. This property of the asthenosphere facilitates the movement of the lithospheric plates. The lithosphere, with the continents on top of it, is being carried by the flowing asthenosphere.



https://www.studyblue.com/notes/note/n/geography-terms/deck/4616076

Figure 6. The Lithosphere and the Asthenosphere

The Core

The core is subdivided into two layers: the inner and the outer core. The outer core is 2900 kilometers below the Earth's surface. It is 2250 kilometers thick and is made up of iron and nickel. The temperature in the outer core reaches up to 2000°C at this very high temperature, iron and nickel melt.

Aside from seismic data analysis, the Earth's magnetic field strengthens the idea that the Earth's outer core is molten/liquid. The outer core is mainly made up of iron and nickel moving around the solid inner core, creating Earth's magnetism.

The inner core is made up of solid iron and nickel and has a radius of 1300 kilometers. Its temperature reaches to about 5000^{o}C. The extreme temperature could have molten the iron and nickel but it is believed to have solidified as a result of pressure freezing, which is common to liquids subjected under tremendous pressure.

What tells us that the inner core is made up of iron?

Aside from the fact that the Earth has a magnetic field and that it must be iron or other materials which are magnetic in nature, the inner core must have a density that is about 14 times that of water. Average crustal rocks with densities 2.8 times that of water could not have the density calculated for the core. So iron, which is three times denser than crustal rocks, meets the required density.

Some clues that the inner core and the outer core are made up of iron include the following:

- Iron and nickel are both dense and magnetic.
- The overall density of the earth is much higher than the density of the rocks in the crust. This suggests that the inside must be made up of something denser than rocks.
- Meteorite analysis have revealed that the most common type is chondrite. Chondrite contains iron, silicon, magnesium and oxygen; some contains nickel. The whole earth and the meteorite roughly have the same density, thus the Earth's mantle rock and a meteorite minus its iron, have the same density.

Activity 2

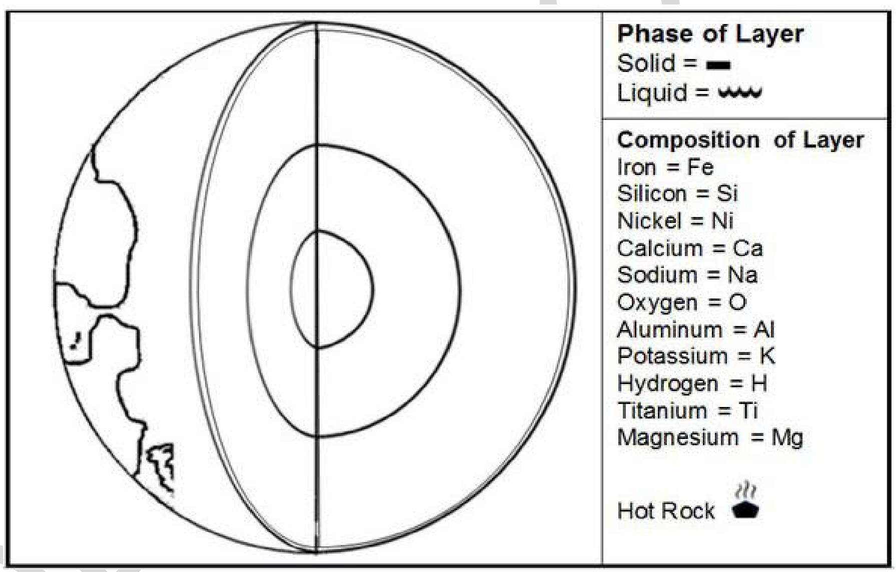
Our Dynamic Earth

Objectives:

- Describe the properties of the layers of the Earth.
- Tell the composition of the layers of the Earth.

Procedure:

1. Label the drawing corresponding to the Earth's layers.
2. Describe the different layers of the Earth using symbols.
3. Choose from the response grid on the right the symbol that you need to finish the figure on the left.
4. Draw the symbol/s in the corresponding layer of the Earth.



Guide Questions:

Q3. What element is the most abundant in the Earth's crust?

Q4. What elements make up most of the mantle?

Q5. What is the special feature of the upper mantle?

Q6. How did scientists come to know that the outer core is liquid?

Q7. What materials make up the inner core?

Q8. Is the inner core solid, liquid, or gas? What keeps it in this phase?

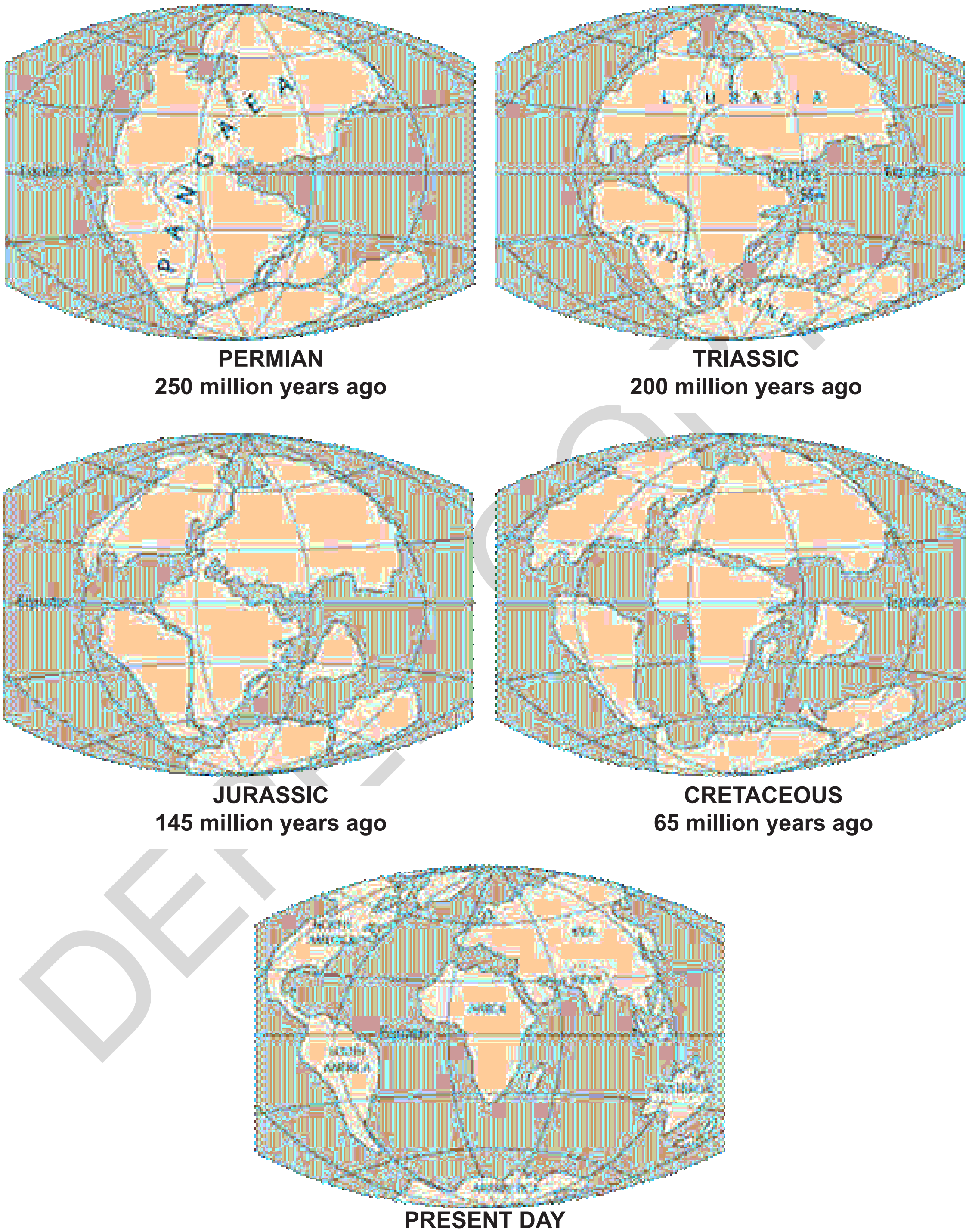
Q9. Compare the inner core and the outer core.

The Earth's Mechanism

The Continental Drift

Have you had the chance to go to a mountain, stand on its peak and look at the beauty that it offers? Do you think it looks exactly the same as before? Perhaps you would think that it might be different - all plain, no plateaus, no mountains. If it wasn't the same 10 years ago, how much different is it 10 million years ago, 100 million years ago?

In 1912, Alfred Wegener (pronounced as vey-guh-nuh r), a German meteorologist, proposed a theory that about 200 million years ago, the continents were once one large landmass. He called this landmass Pangaea, a Greek word which means "All Earth." Figure 7 shows how Pangaea evolved into how the continents look today. This Pangaea started to break into two smaller supercontinent called Laurasia and Gondwanaland during the Jurassic Period. These smaller supercontinents broke into the continents and these continents separated and drifted apart since then. Is this idea somehow true? If you lived during Wegener's time, will you believe him?



pubs.usgs.gov

Figure 7. The Evolution of Pangaea

Wegener searched for evidences to support his claim. He noticed the fit of the edges of the continents on the opposite sides of the South Atlantic. His evidences to the Continental Drift Theory includes the distribution of fossils in different continents, rock features, and ancient climates. Let us have a further study on these evidences.

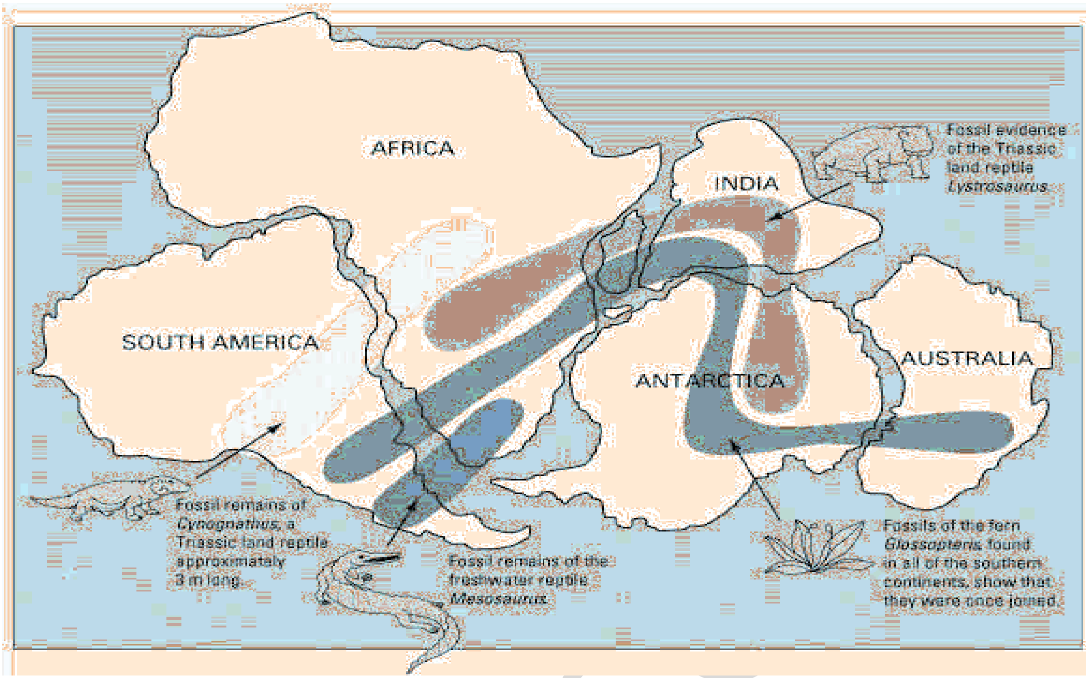
Evidence: The Continental Jigsaw Puzzle

Did it really start as one big landmass? It seems very impossible that the seven continents, which are currently thousands of miles away from each other were actually connected pieces of a supercontinent.

The most visible and fascinating evidence that these continents were once one is their shapes. The edge of one continent surprisingly matches the edge of another: South America and Africa fit together; India, Antarctica, and Australia match one another; Eurasia and North America complete the whole continental puzzle in the north.

Evidence from Fossils

Fossils are preserved remains or traces of organisms (plants and animals) from the remote past. Fossilized leaves of an extinct plant *Glossopteris* were found in 250 million years old rocks. These fossils were located in the continents of Southern Africa, Australia, India, and Antarctica, which are now separated from each other by wide oceans. The large seeds of this plant could not possibly travel a long journey by the wind or survive a rough ride through ocean waves.



Source: http://pubs.usgs.gov/gip/dynamic/continents.html
Figure 8. Distribution of Fossils across Different Continents

Source: fossilmall.com
Figure 9. *Glossopteris* Fossil

Mesosaurus (shown in Figure 10) and *Lystosaurus* are freshwater reptiles. Fossils of these animals were discovered in different continents, such as in South America and Africa. It is impossible for these reptiles to swim over the vast oceans and move from one continent to another. Fossils were also found in Antarctica. Could it be possible that they existed in this region where temperature was very low? Or could it be possible that, long before, Antarctica was not in its current position?

Source: www.busacagallery.com
Figure 10. *Mesosaurus* Fossil

The following activities will give you an idea how the Continental Drift Theory was conceived.

Activity 3

Let's Fit it!

Objectives:

- Find clues to solve a problem.
- Recognize how the Continental Drift Theory is developed.

Materials:

- old newspaper or magazine
- scotch tape

Procedure:

1. Do this activity in a group of five to six members.
2. Obtain a set of torn newspaper page or magazine page from your teacher.
3. Try to fit the pieces together.
4. Use a tape to connect the pieces.

Q10. What features of the newspaper helped you to connect the pieces perfectly?

Q11. How do the lines of prints or texts in the newspaper help you to confirm that you have reassembled the newspaper/magazine page?

Q12. Show proofs that the newspaper is perfectly reassembled.

Activity 4

Drifted Supercontinent!

Objectives:

- Tell the possible direction of motion of the continents as they drifted away.
- Draw fossils of plants and animals as evidences found in the present continents that will help solve the puzzle in the fitting of the drifted continents.
- Reconstruct and describe Pangaea.
- Predict what will happen to the world as the continents continuously move.

Materials:

- photocopy of the seven continents
- world map
- pair of scissors

Procedure:

1. Cut carefully the traces of the seven continents. Warning: Be careful in using the scissors.

2. Sketch the dominant species of plants and animals found in the continents before and after drifting away from each other.

3. Put the cut-outs together.

   Q13. What do the Glossopteris fossils tell us about the early positions of the continents?

   Q14. If Glossopteris fossils were found in Antarctica, what was the climate of this continent before?

   Q15. If the climate and the position of a place are relative to each other, where then was the initial location of Antarctica 250 million years ago?

   Q16. What does the presence of Mesosaurus fossils tell about the initial location and positioning of South America, Africa, and Antarctica?

4. Make sure that you put fitting edges of the continents side by side to form the supercontinent Pangaea.

   Q17. What clues are useful in reconstructing Pangaea?

   Q18. Which continents do you think were neighbors before?

   Q19. Is there a possibility that the current location of a continent would be different 100 years from now?

   Q20. Where do you think was the Philippines located during the time that the Pangaea existed? Research on how the Philippine islands emerged.

5. Compare Pangaea with the world map.

6. Now move one continent relative to its current location. Observe carefully the direction of its motion as it assumes its current location and position. Record your observation.

7. Do the same procedure to the other continents. Record your observations.

   Q21. If the continents will continue to move, try to predict the Philippines' location 100 million years from now.

Evidence from Rocks

Fossils found in rocks support the Continental Drift Theory. The rocks themselves also provide evidence that continents drifted apart from each other. From the previous activity, you have learned that Africa fits South America. Rock formations in Africa line up with that in South America as if it was a long mountain range.

How come these rock layers in different continents line up together with layers that exactly matched?

The folded cape mountains of South America and Africa line up perfectly as if they were once a long mountain range.

Coal Deposits

Coal beds were formed from the compaction and decomposition of swamp plants that lived million years ago. These were discovered in South America, Africa, Indian subcontinent, Southeast Asia, and even in Antarctica. How is a coal bed formation possible in Antarctica?

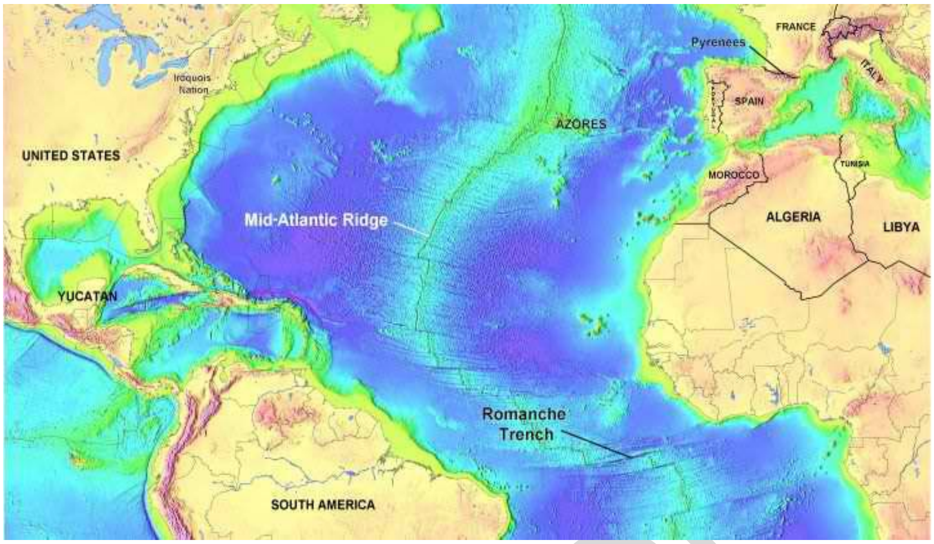
The current location of Antarctica could not sustain substantial amount of life. If there is a substantial quantity of coal in it, thus, it only means that Antarctica must have been positioned in a part of the Earth where it once supported large quantities of life. This leads to the idea that Antarctica once experienced a tropical climate, thus, it might have been closer before to the equator.

The Seafloor Spreading

The question as to how the drifting took place left the Continental Drift Theory blurry. Despite the evidences presented by Wegener, his idea that the continents were once joined together was not accepted by the scientific society until the 1960s. He wasn't able to explain how this drifting took place. This made scientists conduct further studies in search for the answer.

During the 1950s and 1960s, new techniques and modern gadgets enabled scientists to make better observations and gather new information about the ocean floor. With the use of sonars and submersibles, scientists had a clearer view of the ocean floors. They have discovered underwater features deep within the ocean.

Scientists found a system of ridges or mountains in the seafloor similar to those found in the continents. These are called mid-ocean ridges. One of these is the famous Mid-Atlantic Ridge (Figure 11), an 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.



Source: huttoncommentaries.com
Figure 11. The Mid-Atlantic Ridge

In the early 1960's, scientist Harry Hess, together with Robert Dietz, suggested an explanation to the continental drift. This is the Seafloor Spreading Theory. According to this theory, hot, less dense material from below the earth's crust rises towards the surface at the mid-ocean ridge. This material flows sideways carrying the seafloor away from the ridge, and creates a crack in the crust. The magma flows out of the crack, cools down and becomes the new seafloor.

Overtime, the new oceanic crust pushed the old oceanic crust far from the ridge. The process of seafloor spreading allowed the creation of new bodies of water. For example, the Red Sea was created as the African plate and the Arabian plate moved away from each other. Seafloor spreading is also pulling the continents of Australia, South America, and Antarctica away from each other in the East Pacific Rise. The East Pacific Rise is one of the most active sites of seafloor spreading, with more than 14 centimeters every year.

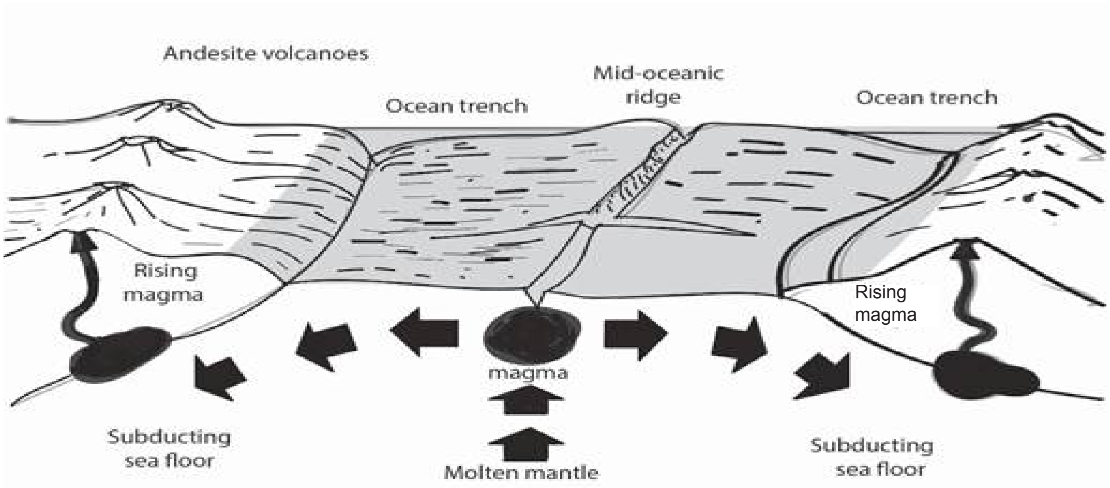


Figure 12. Diagram of Seafloor Spreading

In the place where two oceanic plates collide or where an oceanic plate and a continental plate collide, a subduction zone occurs. As the new seafloor is formed at the mid-ocean ridge, the old seafloor farthest from the ridge is destroyed at the subduction zone.

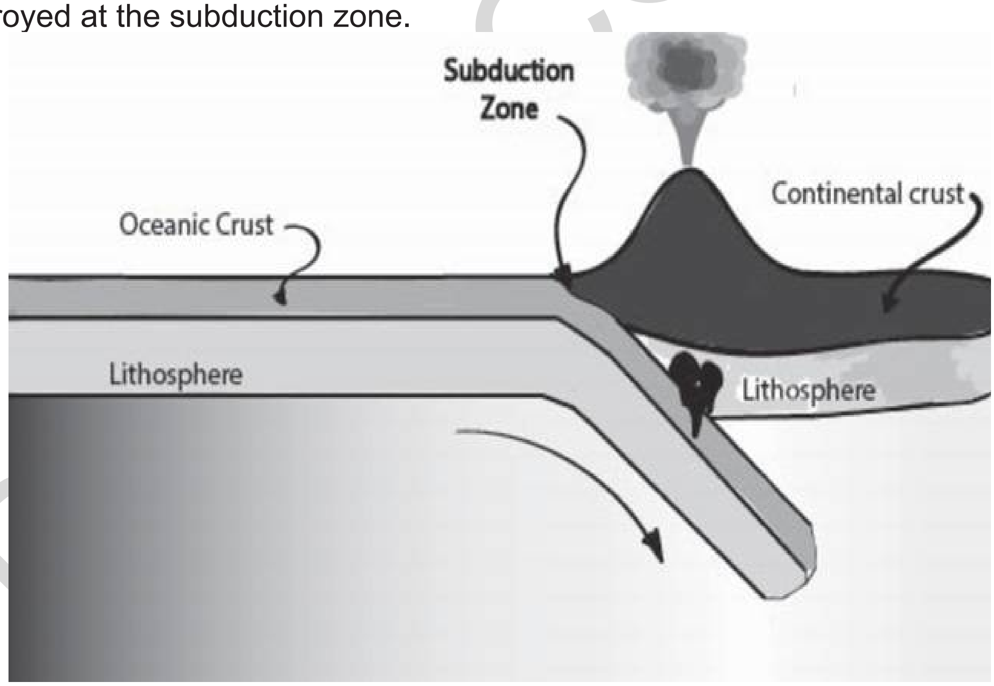


Figure 13. Subduction Zone

The rate of formation of a new seafloor is not always as fast as the destruction of the old seafloor at the subduction zone. This explains why the Pacific Ocean is getting smaller and why the Atlantic Ocean is getting wider. If subduction is faster than seafloor spreading, the ocean shrinks. When the seafloor spreading is greater than the subduction, then the ocean gets wider.

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 those at the continents.

The Seafloor Spreading Theory contradicts a part of the Continental Drift Theory. According to this theory, continents moved through unmoving oceans and that larger, sturdier continents broke through the oceanic crust. Whereas, the seafloor spreading shows that the ocean is the actual site of tectonic activity.

Magnetic Reversal

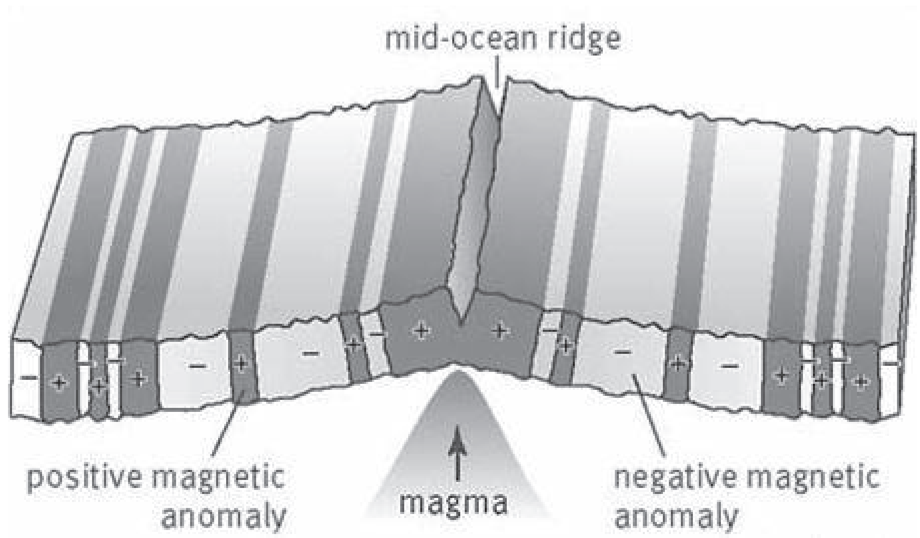
Seafloor spreading was strengthened with the discovery that the magnetic rocks near the ridge follow a pattern aside from the fact that rocks near the ridge are remarkably younger than those father from the ridge.

A magnetic compass tells us directions on Earth. It also proves that the Earth has a magnetic field. The needle of a magnetic compass usually points to the North Pole of the Earth which is actually the South Magnetic Pole at present.

The Earth's magnetic field is generated in the very hot molten outer core and has already existed since the birth of our planet. The Earth's magnetic field is a dipole, one that has a North Pole and a South Pole.

What is magnetic reversal? How does magnetic reversal happen and how does it prove seafloor spreading? Magnetic reversal is also called magnetic 'flip' of the Earth. It happens when the North Pole is transformed into a South Pole and the South Pole becomes the North Pole. This is due to the change in the direction of flow in the outer core.

Magnetic reversals happened many times in the past. The occurrence of magnetic reversals can be explained through the magnetic patterns in magnetic rocks, especially those found in the ocean floor. When lava solidifies, iron bearing minerals crystallize. As these crystallize, the minerals behave like tiny compasses and align with the Earth's magnetic field. So when magnetic reversal occurs, there is also a change in the polarity of the rocks. This allowed scientists to visualize the magnetic stripes in the ocean floor similar to Figure 14, and to construct a magnetic polarity time scale similar to Figure 15.



http://www.yourdictionary.com/magnetic-reversal

Figure 14. Magnetic Reversal

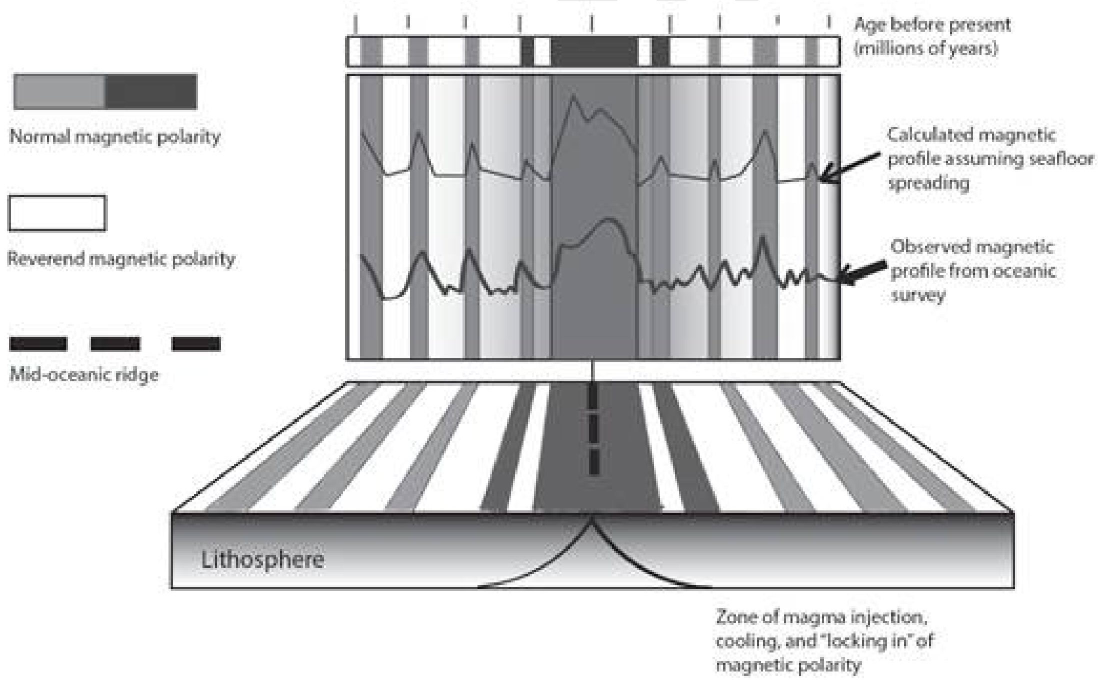


Figure 15. Magnetic Polarity Time Scale

Over the last 10 million years, there has been an average of 4 to 5 reversals per million years. New rocks are added to the ocean floor at the ridge with approximately equal amounts on both sides of the oceanic ridge. The stripes on both sides are of equal size and polarity which seemed to be mirror images across the ocean ridge. What does this indicate? It indicates that indeed, the seafloor is spreading.

Try the following activity to further explore what happens deep under the ocean at the Mid-Atlantic Ridge.

Activity 5

Split and Separate!

(Adapted)

Objectives:

- Simulate and describe the seafloor spreading process.
- Realize the importance of the seafloor spreading process relative to the Continental Drift Theory.

Materials:

- board paper
- bond paper
- colored pencil
- pair of scissors
- ruler

Procedure:

1. Using a colored pencil, draw stripes across one sheet of bond paper parallel to the short sides of the paper. The stripes should vary in spacing and thickness.
2. Fold the bond paper in half lengthwise.
3. Write the word "*Start*" at the top of both halves of the paper. It should look like the figure on the right.
4. Cut the bond paper in half along the dashed line to form two strips.
5. Take the board paper and make three (3) 11-cm long slits as indicated in the illustration.

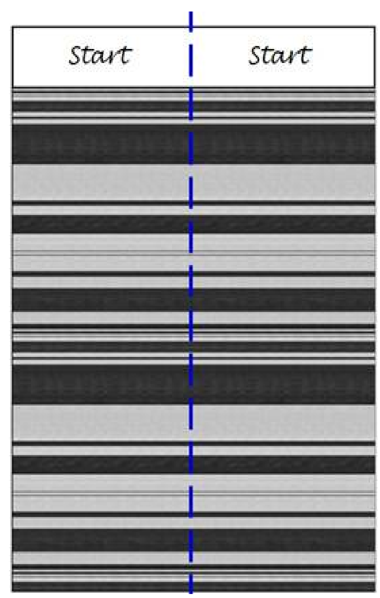
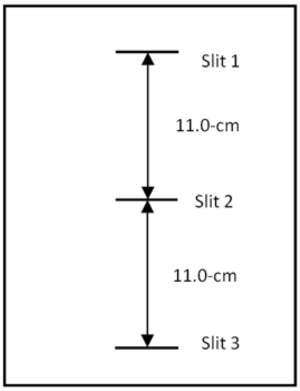


Illustration 1. Bond Paper

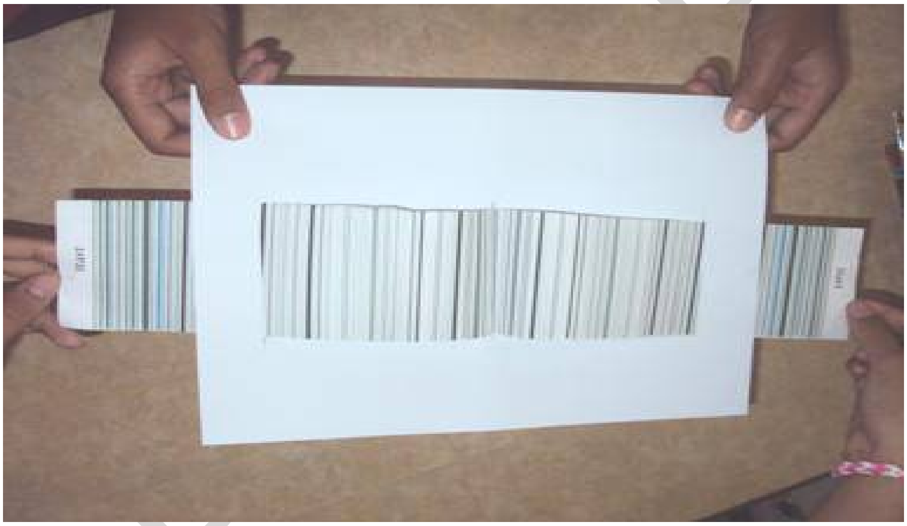
6. The two slits near the edges of the bond paper should be both 11-cm from the center slit.



7. Put the two striped strips of paper together so that the “Start” labels touch one another.

8. Insert the strips up through the center slit, then pull them toward the side slits.

9. Insert the ends of the strips into the side slits. Pull the ends of the strips as shown in the figure below and watch what happens at the center slit.



10. Practice pulling the strips through the slits until you can make the stripes come up and go down at the same time.

Q22. What do the stripes in the paper represent?

Q23. What does the middle slit represent? What occurs in this region?

Q24. What is the role of the mid–ocean ridge in the movement of lithospheric plates?

Q25. How does the new seafloor form at the mid-ocean ridge?

Q26. What process/es happen at the side slits?

Q27. Is the earth getting larger and wider when plates drift away from each other? Explain briefly.

Now that you understand the Seafloor Spreading Theory, try the following activity to find how fast the seafloor is spreading.

Activity 6

How fast does it go!

Adapted (Glencoe Earth Science student edition copyright 2002)

Objectives:

- Analyze a magnetic polarity map.
- Use legends and scales of the map properly.
- Calculate the rate of seafloor spreading using magnetic clues.

Materials:

- magnetic polarity map
- metric ruler
- pencil

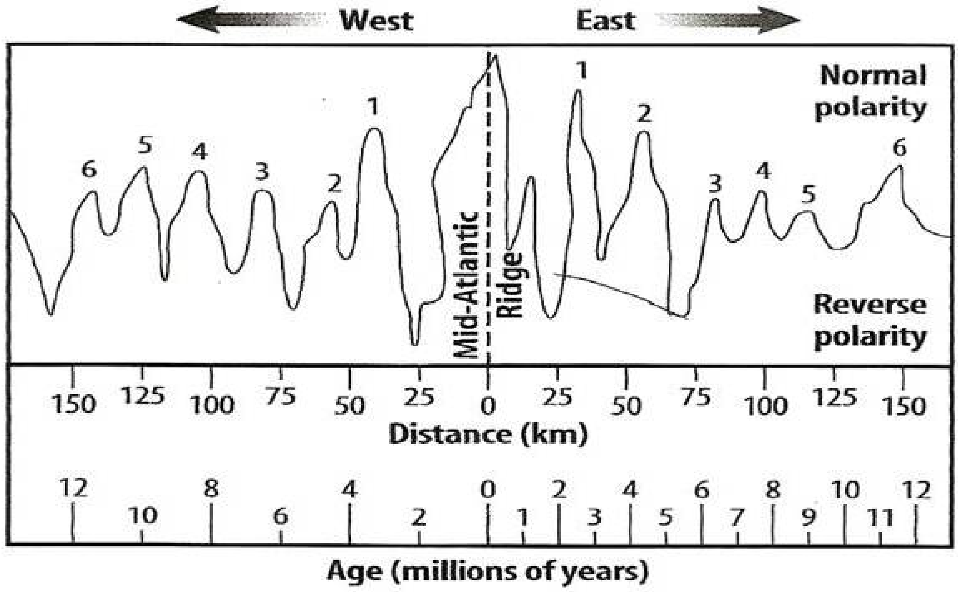
Procedure:

1. Study the magnetic polarity map. You will be working only with normal polarity readings, these are the peaks above the baseline on the top half of the graph.

2. Place the long edge of the ruler vertically on the graph. Align the ruler with the center peak 1 of the Mid-Atlantic Ridge.

3. Determine and record the distance and age that line up with the center of peak 1 west. Repeat this process for peak 1 east of the ridge.

4. Calculate the average age and distance for this pair of peaks.



Magnetic polarity map

5. Repeat steps 2 to 4 for the remaining pairs of normal polarity peaks.

6. Calculate the rate of movement in centimeters per year using the formula

   Rate = distance / time.

   Q28. How far do the plates move away from each other every year?

   Q29. If Africa is approximately 2400 km away from the Mid-Atlantic Ridge, how long ago was it when Africa was directly at or near the Mid-Atlantic Ridge?

Plate Tectonic Theory

What causes tectonic plates to move? This is one of the main questions that has remained unanswered since Alfred Wegener proposed the Continental Drift Theory.

The Plate Tectonic Theory provided an explanation about the movement of the lithospheric plates. This theory evolved from the two former theories and was developed during the first decades of the 20th century.

The Earth's lithosphere is divided into several plates. As you have already learned, these plates ride over the weak asthenosphere. There are three types of plate movements – separation of two plates (divergent), collision of two plates (convergent) and sliding past each other (transform).

What facilitates the movement of the plates? Heat is produced in the core that produces convection in the mantle. This convection causes the plate to move around. To further understand this process, try the following activity.

Activity 7

Push me up and aside!

(Adapted)

Objectives:

- Explain what causes the tectonic plates to move.
- Enumerate the factors that cause tectonic plates to move.
- Realize the importance of the creation of convection current underneath the earth.

Materials:

- dropper
- food color
- 1000 mL beaker
- 700 mL water
- 3-5 small / light wood blocks
- hotplate/alcohol burner & tripod

Procedure:

1. Pour 700 mL of water into the beaker.

2. Place the beaker on a hotplate and heat it. Give ample time for the water to heat up.

   Warning: Make sure that you know how to operate a hotplate.
   Wear heat resistant gloves to protect your hands.
   In the absence of a hotplate, you can use an alcohol burner.

3. Add a few drops of food coloring to the water in the beaker.

4. Looking from the side of the dish, observe what happens in the water.

   Q30. How does the food coloring behave?

Q31. What do you call this behavior?

Q32. Enumerate the factors that cause the formation of a current.

5. Put several light wood blocks in the center of the heated near to boiling water.

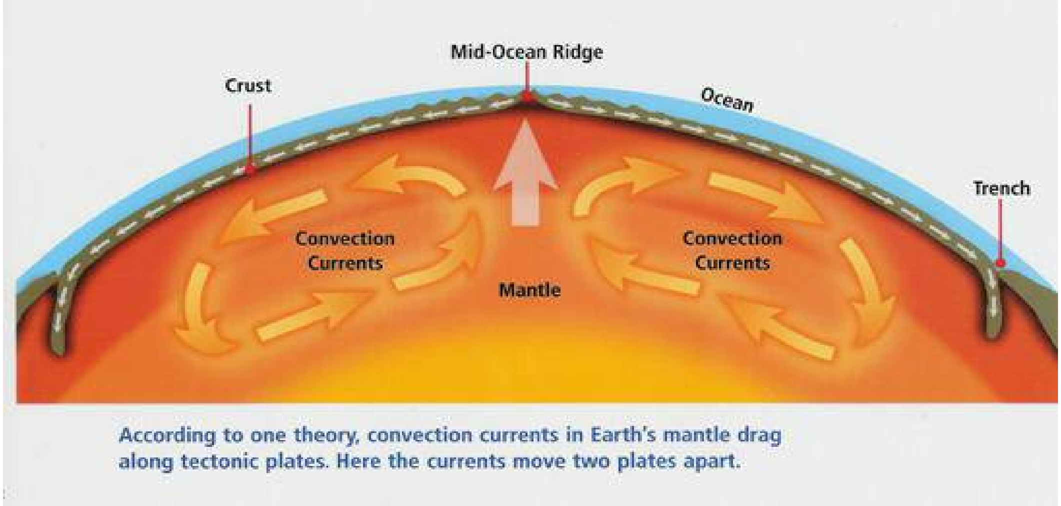
   Q33. What happens to the blocks? What does this resemble?

6. Illustrate your observations.

Convection Current

As a substance like water is heated, the less dense particles rise while denser particles sink. Once the hot less dense particles cool down, they sink, and the other less dense particles rise. This continuous process is called convection current. This is exactly what happens in the Earth's mantle. The hot, less dense rising material spreads out as it reaches the upper mantle causing upward and sideward forces. These forces lift and split the lithosphere at divergent plate boundaries. The hot magma flows out of the mantle and cools down to form the new ocean crust. The downward movement of the convection current occurs along a convergent boundary where the sinking force pulls the tectonic plate downward.

The convection currents rotate very slowly, as they move and drag the plates along. Because of convection current, the tectonic plates are able to move slowly along the tectonic boundaries, pushing each other, sliding past each other and drifting away from each other. This process is further illustrated in Figure 16 below.



Source: www2.chilton.k12.wi.us
Figure 16. Convection Current in the Mantle

As an oceanic crust moves away from a divergent boundary, it becomes denser than the newer oceanic crust. As the older seafloor sinks, the weight of the uplifted ridge pushes the oceanic crust toward the trench at the subduction zone. This process is called ridge push.

Slab pull is the other possible process involved in the tectonic plate movement. The weight of the subducting plate pulls the trailing slab into the subduction zone just like a tablecloth slipping off the table and pulling items with it.

Now that you understand what happens inside the Earth and its effects on the Earth's surface, you should be able to realize that the tectonic activities at the surface just like volcanic eruptions and earthquakes are inevitable. You should view the Earth as a dynamic planet and still the most fascinating planet for it offers you a home that no other planet can. Since you can't prevent these tectonic activities from happening, the following performance task will enable you to contribute meaningfully in minimizing the damage that these phenomena can bring.

Performance Task

Goal

To design a scheme to inform local folks in your hometown about the possibilities of earthquakes, tsunami, and other geologic activities in your area

Role

A project engineer who wants to develop a new subdivision, a realtor who sells a house & lot, a geologist visiting his/her hometown or simply a student seeking to help the government.

Audience

People in your locality

Situation

You are to inform local folks in your hometown about the possibilities of earthquakes, tsunami, and other geologic activities in your area. Most especially, you must bring out in them the sense of being always ready and prepared.

Product

Informative materials about ways to mitigate the effects of tectonic activities-related disasters

Standards

You will be rated according to the following criteria:

Details and Information	4 points
Method of Presentation/Dissemination	4 points
Techniques	4 points
Accuracy	4 points
Feedback/Result	4 points
TOTAL	**20 points**

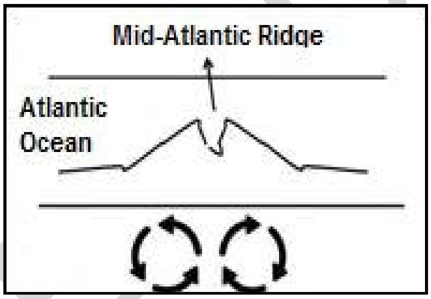
V. Summative Assessment

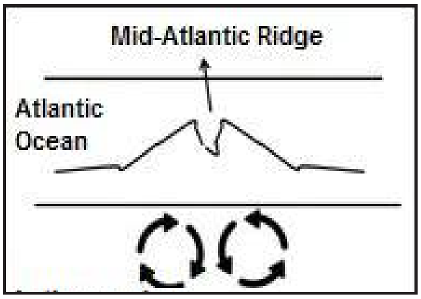
Answer the following questions.

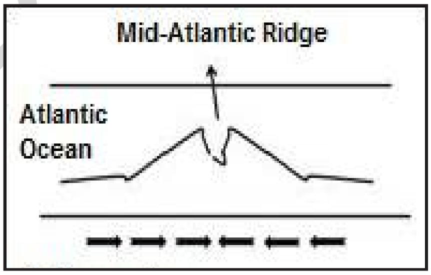
1. In 1912, Alfred Wegener proposed a theory that the Earth is once a single landmass. What is the name of the Mesozoic supercontinent that consisted of all of the present continents?
    a. Eurasia
    b. Laurasia
    c. Pangaea
    d. Gondwanaland

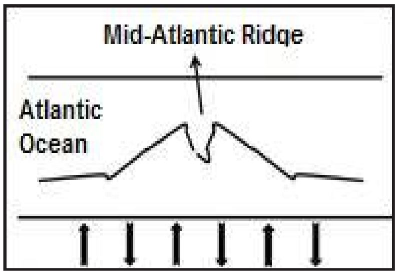
2. Who were the two scientists who proposed the theory of seafloor spreading in the early 1960s?
    a. Charles Darwin and James Hutton
    b. Harry Hess and Robert Dietz
    c. John Butler and Arthur Smite
    d. F. Vine and D. Mathews

3. Which of the following diagrams best illustrates the convection occurring in the mantle?

a.


c.


b.


d.


4. During the 1960s, scientists were already equipped with gadgets needed to explore the deep ocean. What discovery about the ocean floor is associated with the seafloor spreading?
   a. Mountains are denser than the mantle.
   b. The rotational poles of the Earth have migrated.
   c. The crust of the continents is more dense than the crust of the ocean.
   d. The crust of the ocean is very young relative to the age of the crust of the continents.

5. If the Atlantic Ocean is widening at a rate of 3 cm per year, how far (in kilometers) will it spread in a million years?
   a. 3 kilometers
   b. 30 kilometers
   c. 300 kilometers
   d. 3000 kilometers

6. Which of the following increases with distance from a mid-ocean ridge?
   a. the age of oceanic lithosphere
   b. the thickness of the lithosphere
   c. the depth to the sea floor
   d. all of the above

7. Which of the following can you infer from the continuous movement of the lithospheric plates over the asthenosphere?
   a. All the continents will cease to exist.
   b. All the volcanoes in the Philippines will become inactive.
   c. The continents will not be located in the same place as they are now.
   d. The islands of the Philippines will become scattered all over the world.

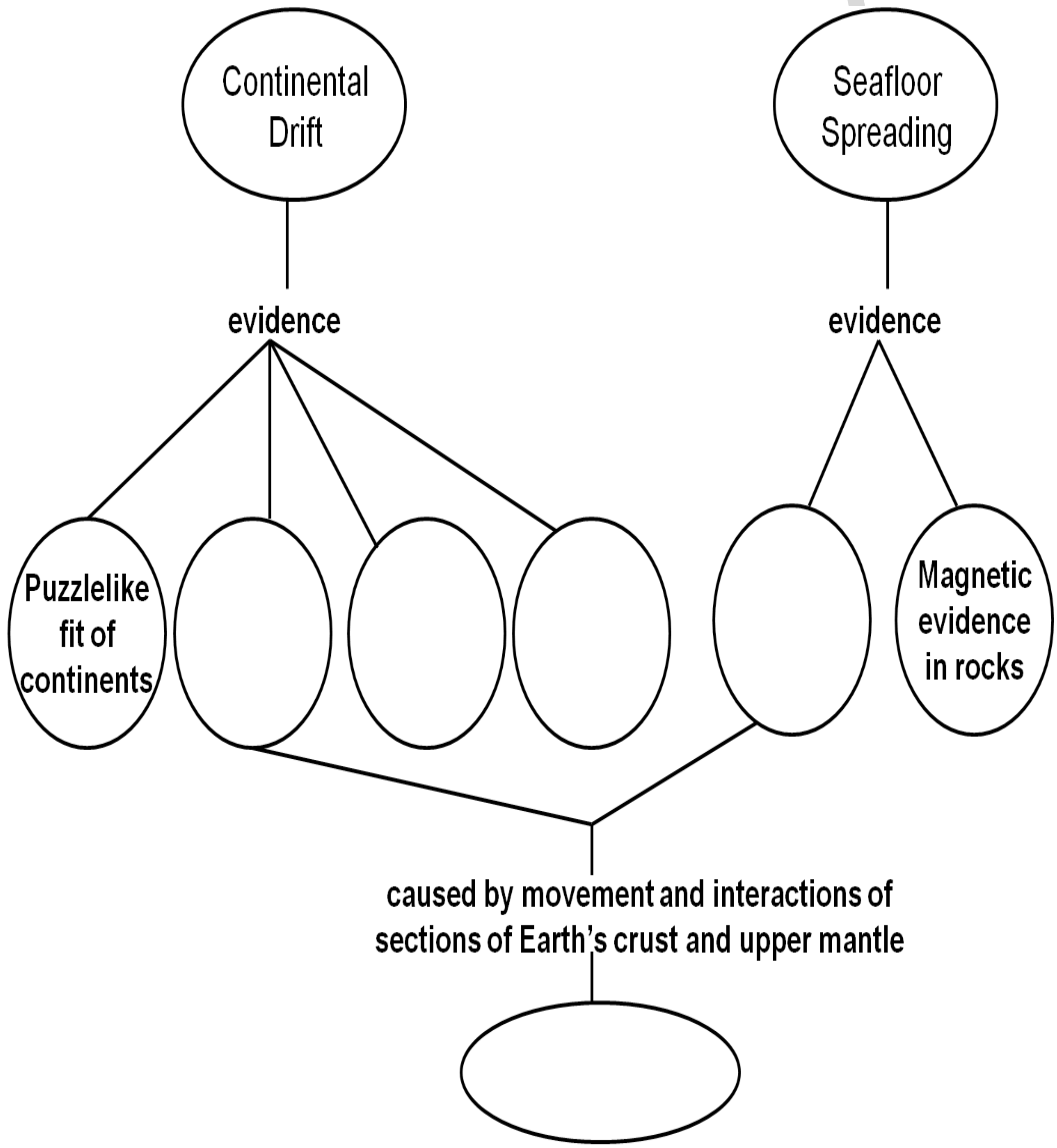
8. If all the inner layers of the Earth are firm solid, what could have happened to Pangaea?
   a. It remained as a supercontinent.
   b. It would have become as it is today.
   c. It would have slowly disappeared in the ocean.
   d. It would have stretched and covered the whole world.

9. Why does the oceanic crust sink beneath the continental crust at the subduction zone?
   a. The oceanic crust has a greater density.
   b. The oceanic crust is pulled downward by Earth's magnetic field.
   c. The oceanic crust is pushed from the ridge.
   d. The continental crust has a denser composition.

10. The lithospheric plates are believed to be moving slowly. What is the driving force that facilitates this movement?

    a. gravitational force of the moon
    b. magnetic force at the poles
    c. convection current in the mantle
    d. the force of the atmosphere

B. Complete the concept map below about continental drift, seafloor spreading, and plate tectonics.



VI. Summary/Synthesis/Feedback

- The Earth is composed of three major layers: the crust, mantle, and core which is subdivided into outer and inner core.
- The crust is the outermost and thinnest layer of the Earth.
- The mantle is the middle layer of the Earth. It makes most of the Earth's volume and mass.
- The crust and a part of the upper mantle make up the lithosphere. The lithosphere is subdivided into portions called lithospheric plates.
- The asthenosphere is the weak layer of the mantle on which the lithosphere floats.
- The outer core is made up of molten material and accounts for the Earth's magnetic field.
- The inner core is the deepest layer of the Earth. It is made up of solid nickel and iron. The temperature in the inner core reaches as high as 5000°C.
- The speed, reflection and refraction properties of seismic waves are used by scientists to study the structure and composition of the Earth's interior.
- The Continental Drift Theory of Alfred Wegener states that the continents were once part of a large landmass called Pangaea which drifted away from each other. The continents moved away from each other towards their current positions.
- Alfred Wegener based his theory on evidences from fossils imbedded in rocks and rock formations.
- Seafloor spreading is believed to occur as hot magma rises at the rift in the mid-ocean ridge. This magma cools down and becomes the new seafloor as it pushes the former.
- The old seafloor is destroyed at the subduction zone and melts inside the mantle.
- The age of rocks and the magnetic stripes in the ocean floor support the Seafloor Spreading Theory.
- The Theory of Plate Tectonics helps explain the formation and destruction of the Earth's crust and its movement over time.
- Scientists believe that the plates' movement is due to convection currents in the mantle.

Glossary of Terms

Asthenosphere — soft, weak upper portion of the mantle where the lithospheric plates float and move around

Continental Drift Theory — states that all the continents were once one large landmass that broke apart, and where the pieces moved slowly to their current locations

Convection current — current in the mantle because of the heat from the inner layers of the Earth, and is the force that drives the plates to move around

Lithosphere — the topmost, solid part of the Earth that is composed of several plates

Lithospheric Plates — the moving, irregularly-shaped slabs that fit together to form the surface of the Earth

Mid-ocean ridge — area in the middle of the ocean where a new ocean floor is formed when lava erupts through the cracks in the Earth's crust

Mohorovičić Discontinuity (Moho) — the boundary that separates the crust and the mantle

Plasticity — the ability of solid to flow

Seafloor spreading — process by which new ocean floor is formed near the mid-ocean ridge and moves outward

Subduction — the process in which the crust plunges back into the Earth

Tectonics — branch of geology that deals with the movements that shape the Earth's crust

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