CORE CONCEPTS

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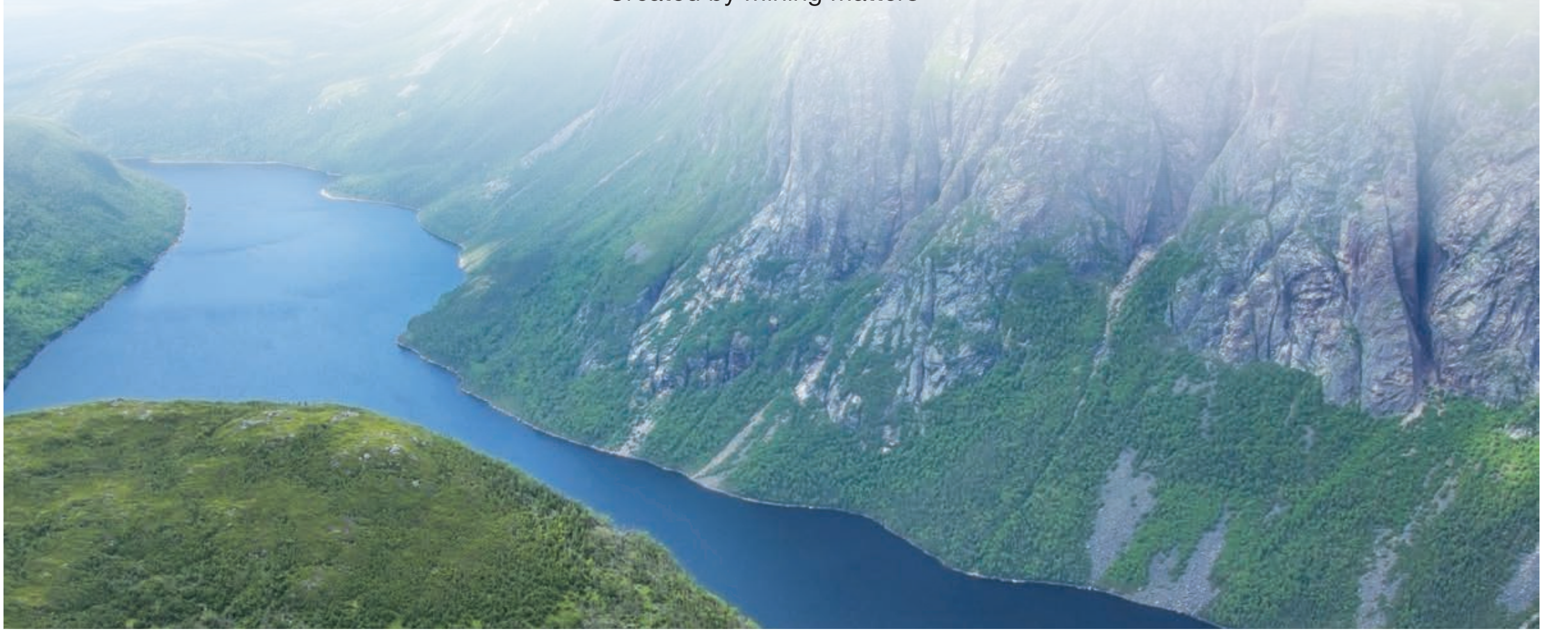

Structure of the Earth

Did you know that there are complementary and additional resources that will facilitate with the delivery of this topic? Please contact Mining Matters and we'd be happy to assist. Be sure to state, "Core Concepts order request" in the subject line of the email and/or the fax cover sheet.

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1 TECTONIC PLATES THE MOVING FOUNDATION OF THE EARTH'S SURFACE

MATERIALS

- World map
- Craft knife
- Pens and pencils
- Figure: *Tectonic Plates* (Displayed on available classroom projection technology)
- Handout: *Diagram of Tectonic Plates*
- Handout: *Diagram of Tectonic Plates – The Moving Foundation of the Earth's Surface*
- Handout: *Tectonic Plates – The Moving Foundation of the Earth's Surface Information Bulletin*
- Handout: T*ectonic Plates – The Moving Foundation of the Earth's Surface Activity*
- Optional online book: *ROCK Ontario book*

  Available Here!
  http://www.mndm.gov.on.ca/en/mines-and-minerals/geology

Consumables:

- Thick Cardboard (side of an old cardboard box)
- Tracing paper

SUMMARY OF TASK

Students will:

- Understand and be able to describe the processes involved in mountain formation and in the folding and faulting of the Earth's surface.

EARTH SCIENCE LITERACY PRINCIPLE(S)

BIG IDEA 1 Earth scientists use repeatable observations and testable ideas to understand and explain our planet.

BIG IDEA 3 Earth is a complex system of interacting rock, water, air, and life.

BIG IDEA 4 Earth is continuously changing.

OBJECTIVES

1. Participate in teacher-led discussion about plate tectonics based on the Information Bulletin.
2. Answer questions based on a sight passage.

INSTRUCTIONS

Engage

1. Distribute and review the handout: *Tectonic Plates – The Moving Foundation of the Earth's Surface Information Bulletin.*

Explore

2. Have students examine the world map and examine how the continents could have once fit together.

Explain

3. Distribute the handouts: *Diagram of Tectonic Plates – The Moving Foundation of the Earth's Surface* and *Diagram of Tectonic Plates* and discuss student observations.
4. Display the figure: *Diagram of Tectonic Plates.*

Elaborate

5. Have students copy a map of the world onto tracing paper with a red pen. Then turn the paper over and rub the pencil firmly back and forth across the back of the red line.
6. Turn the tracing paper back onto the right side and place it on the piece of thick cardboard.
7. Draw over the outline of the world map again, pressing down firmly. The pencil on the back of the right side of the tracing paper will transfer onto the cardboard.
8. CAREFULLY, using the craft knife, cut around the continents.
9. Using the continental jigsaw pieces, arrange the continents so that they fit together as a single land mass (i.e. create Pangea).

Evaluate

10. Have students answer the questions on the handout: The Moving Foundation of the Earth's Surface Activity.

 To further student learning and inquiry, encourage students to visit, The Dynamic Earth: The story of plate tectonics, http://pubs.usgs.gov/gip/dynamic/dynamic.html

SUPPORTING INFORMATION

Key Words:

Basic Terms: Pangea, continental drift, convection, plate tectonics, hot spot, Mid-Atlantic ridge, divergent, hypothesis, convergent

Secondary Terms: paleontologists, meteorologists, geologists, subduction zone

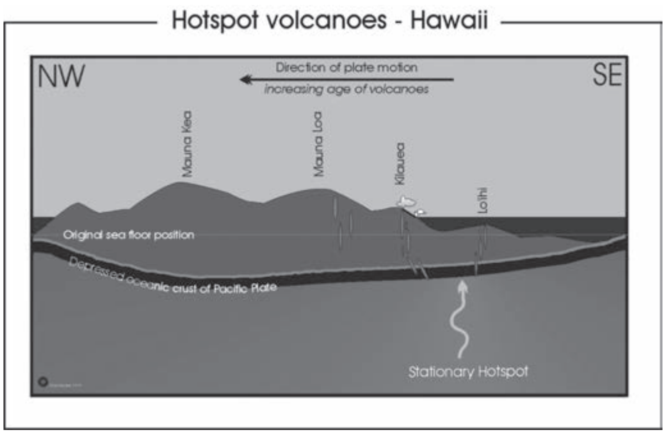
SAFETY

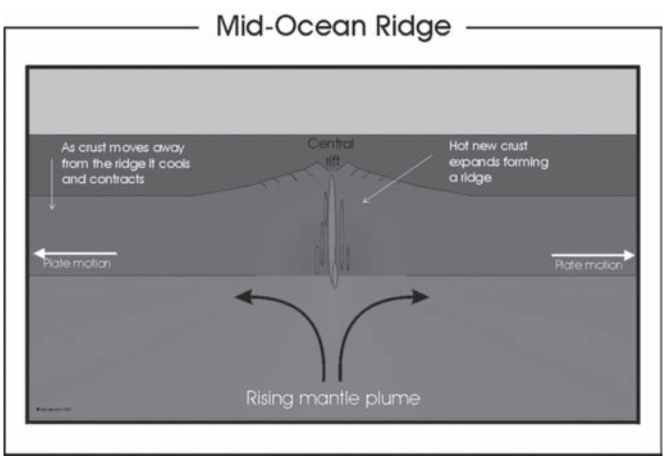
- When using a craft knife always cut away from you and hold the cardboard firmly. Make sure you are using a sharp knife.

Source: http://pubs.usgs.gov/publications/text/dynamic.html - US Geological Survey. This site provides a very comprehensive and excellent source of information and diagrams regarding the theory of plate tectonics.

THE MOVING FOUNDATION OF THE EARTH'S SURFACE

When we look at a map of the world or a globe we can see that the Earth has seven continents. However, when we look more closely we can see that the eastern coastline of South America and the western coastline of Africa fit together like pieces of a jigsaw puzzle – if the Atlantic Ocean were removed and the continents were put together. There are other matching outlines where Canada would piece together with Greenland if the Atlantic Ocean did not separate them. Is it possible that at one time the continents were actually a single land mass with no oceans between them?



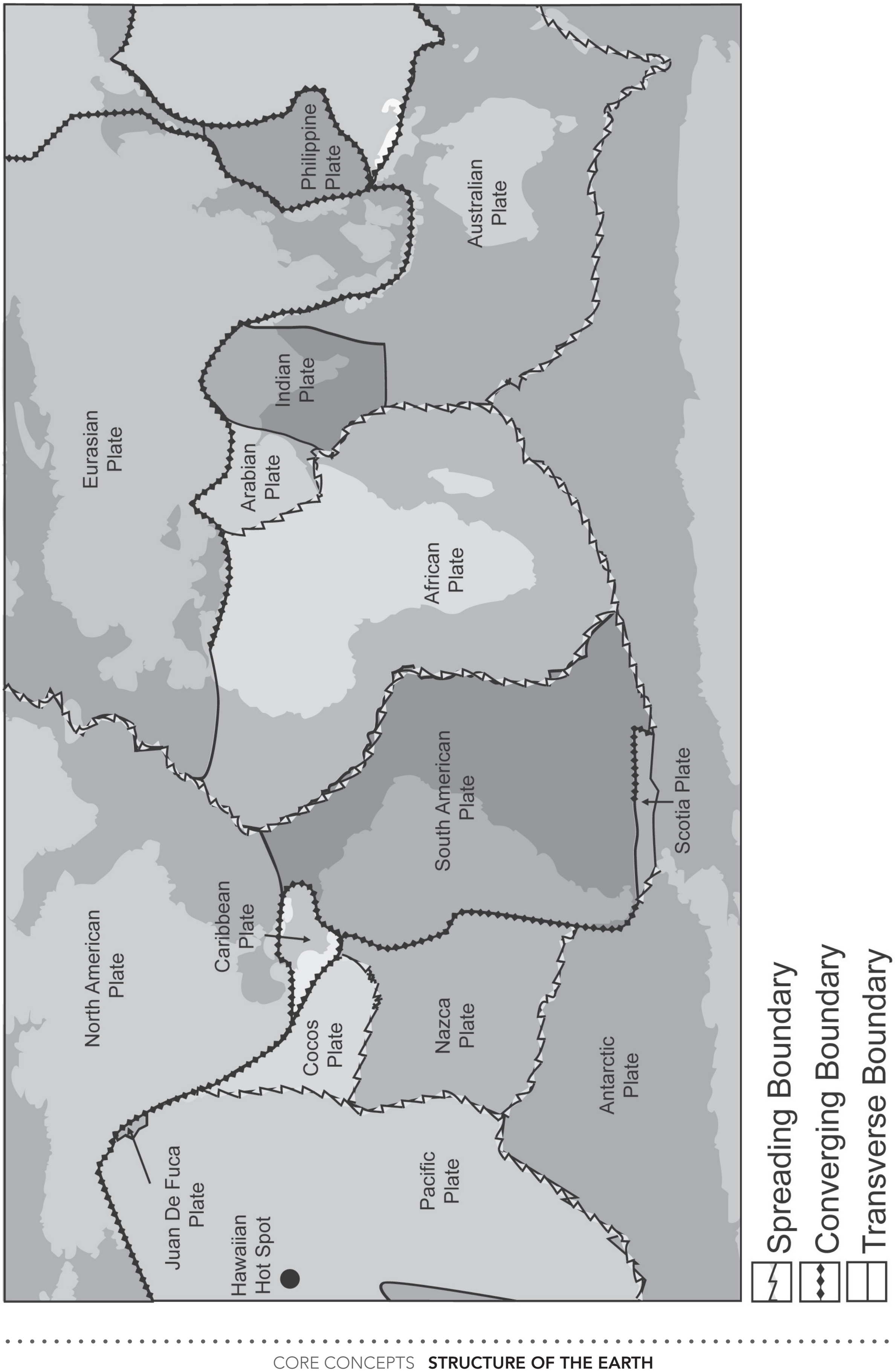


Alfred Wegener, a German *meteorologist*, believed that the continents fit together in the past. *Paleontologists* found the same type of fossils in both South America and Africa, and guessed that the continents were once connected. Wegener had always wondered about the jigsaw-puzzle fit of the continents and this together with the paleontologist's findings led him to come up with a **hypothesis** or scientific idea called **continental drift**. Wegener's theory proposed that at one time all of the continents had been united – a supercontinent – which he named **Pangaea** – and that about 200 million years ago it had begun to break into individual pieces, or continents, slowly moving into their present position, the gaps between the continents becoming oceans.

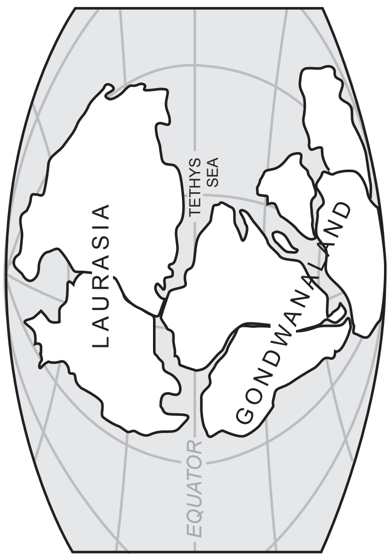
In 1928, a British *geologist* named Arthur Holmes published an article that discussed a force that could explain how the continents were driven apart. Holmes proposed the presence of thermal **convection** currents, or currents of heat, in the interior of the Earth. According to Holmes, these currents rose from the interior of the Earth to the base of the continents, stretching and breaking the continental masses apart.

In 1963, the idea of continental drift was further developed into the concept of **plate tectonics** by Canadian Earth scientist Tuzo Wilson who taught at the University of Toronto and was the director of the Ontario Science Centre until his death in 1993. His main contribution to the theory of plate tectonics was the recognition of hot spots in the mantle. The chain of Hawaiian islands formed a **hot spot** in the Pacific ocean. Wilson's idea is regarded as one of the main advancements in thinking about how the Earth works.

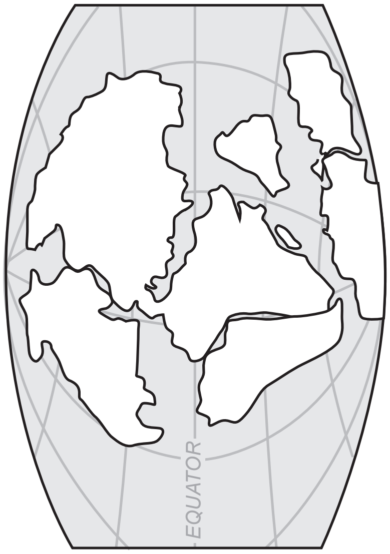
The Earth's surface is divided into about 10 rigid sections, called **tectonic plates**. Convection forces move the plates relative to each other. As the plates move, their boundaries behave in two general ways – **divergent** (spreading) and **convergent** (colliding). New rock is generated at divergent plate boundaries as the plates pull apart. An example of this is the **Mid-Atlantic ridge** in the middle of the Atlantic ocean floor which behaves like two giant conveyor belts slowly moving in opposite directions as they transport newly formed oceanic plate away from the ridge crest at about 3 cm per year. The size of the Earth has not changed implying that the tectonic plate must be destroyed at about the same rate as it is being created. Such destruction (recycling) of rock takes place along convergent plate boundaries where plates are moving toward each other, and sometimes one plate sinks under another. The location where sinking of a plate occurs is called a *subduction zone*. Volcanoes are often located on the surface of the Earth above a subduction zone. Other times when plates collide they crumple up along their edges, creating mountains. An example of a convergent plate boundary is along the west coast of Canada where the Pacific plate is sliding under the North American plate.


Eurasian Plate
Philippine Plate
Australian Plate
Indian Plate
Arabian Plate
African Plate
South American Plate
Scotia Plate
Caribbean Plate
North American Plate
Cocos Plate
Nazca Plate
Antarctic Plate
Pacific Plate
Juan De Fuca Plate
Hawaiian Hot Spot
Spreading Boundary
Converging Boundary
Transverse Boundary

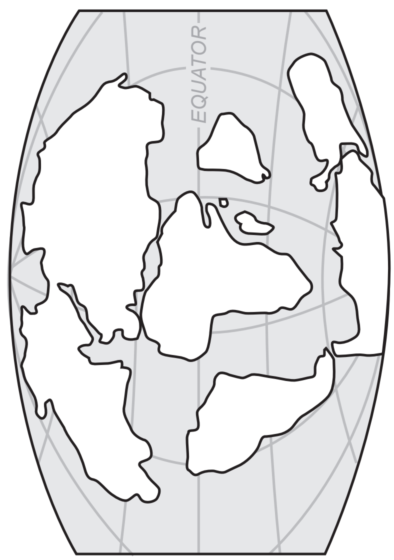
225 million years ago



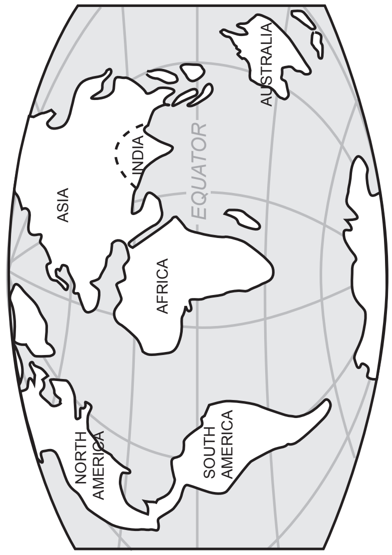
200 million years ago



135 million years ago



65 million years ago



Present Day

1 ACTIVITY QUESTIONS

1. In a short paragraph (4-6 complete sentences) describe the development of the Plate Tectonic theory from its origins in the hypothesis of Continental Drift.

2. What is a spreading boundary? Describe the location of two examples of this type of boundary.

3. Define in complete sentences:

Pangaea

continental drift

tectonic plates

subduction zone

4. What two land masses did Pangaea break-up into and how many years ago was it?

2 HEAT – A POWERFUL FORCE IN THE EARTH

MATERIALS

- Shallow clear heat proof dish – approximately 23 cm x 23 cm (9” x 9”)
- Wooden blocks (2) - 20 cm long pieces measuring, 5 cm x 10 cm (8” long, measuring 2” x 4”)
- Eye dropper
- Globe or world map
- Handout: *Heat – A Powerful Force In the Earth Information Bulletin*
- Handout: *Heat – A Powerful Force In the Earth Activity*

Consumables:

- Cooking oil
- Food colouring
- Votive candle

SUMMARY OF TASK

Students will:

- Understand and be able to describe the processes involved in convection currents.

EARTH SCIENCE LITERACY PRINCIPLE(S)

BIG IDEA 4 Earth is continuously changing.

OBJECTIVES

1. Participate in Teacher led discussion about the Earth’s formation.
2. View and explain convection experiment.

INSTRUCTIONS

Engage

1. Engage students in an introductory discussion of plate tectonics by looking at the globe and how the continents appear to ‘fit’ together. Have students think about how this movement could occur.
2. Run the Convection Experiment and have students take notes.
   a. Place two wooden blocks on a level surface, a little less than the width of the dish. Put a votive candle between them and light it.
   b. Half-fill a heatproof dish with cooking oil. Position it firmly on the blocks. Fill an eyedropper with food dye. Place the eyedropper in the oil, near the bottom of the dish. Squeeze a little food dye from the dropper into the bottom of the dish.
   c. As the oil at the bottom of the dish heats, it will rise, carrying the food dye to the surface. Once at the surface, the food colouring is forced to spread out as the currents keep pushing up from below. As the blobs cool, they get heavier and sink back down to rejoin the pool of food colouring on the bottom. *Source: John Farndon’s How the Earth Works (1992).*

Explore

3. Distribute and review the handout: *Heat – A Powerful Force In the Earth Information Bulletin.*

Explain

4. Discuss student observations and knowledge from the Information Bulletin as a group.

Elaborate

5. Once all the observations have been noted, have students complete handout: *Heat – A Powerful Force In the Earth Activity.*

Evaluate

6. Ask students to research and draw a labelled diagram illustrating an example of convection observed in their daily lives.

SUPPORTING INFORMATION

Key Words:

Basic Terms: inner core, outer core, mantle, lower mantle, upper mantle, transition zone, lithosphere, asthenosphere, convection, lava, magma, tectonic plates, fault, crust

Secondary Terms: convection current, conduction, geothermal, gradient

SAFETY

- The convection demonstration with the wooden blocks and heatproof dish must be performed on a very steady and level surface. It must also be remembered that this demonstration involves heated oil and a lit candle – and CAUTION must be used. REMEMBER – the oil must only be heated – it should under no circumstances be allowed to boil – it is to ensure this, that the heating source used is small – do not substitute another heating source for the votive candle.

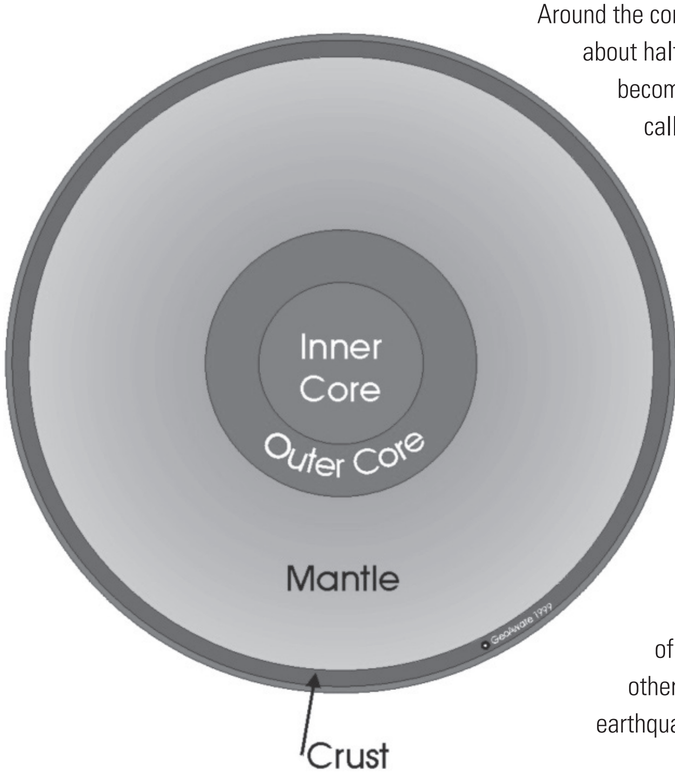
HEAT – A POWERFUL FORCE IN THE EARTH

If you were to go deeper and deeper down into the Earth, it gets hotter and hotter. You can see how hot the interior of the Earth is when you watch videos of volcanic eruptions around the world – such as in Hawaii or Mount Etna in Sicily, Italy. Red-hot molten rock from inside the Earth erupts out of the Volcano. The tremendous heat inside the Earth melts the rock. We call molten rock **magma**. When magma emerges on the surface during a volcanic eruption it is called **lava**.

You may think the Earth beneath your feet is solid and unchanging. In fact, it is constantly moving. Just as water and air rise when heated, magma rises too. The enormous temperature in the Earth's interior melts and mixes the magma, driving it upwards. The hot magma cools as it rises toward the Earth's surface. As it cools, it becomes denser and eventually sinks back down again deeper into the Earth. This circular flow of magma is known as **convection**. We can see convection in everyday life when a liquid is heated. However, unlike heating water, the convection in the Earth is very slow because the rock and magma are very dense.

The Earth is made up of different layers which each play a different role in this convection. The centre of the Earth is approximately 6400 km below the surface. At the centre is the **inner core**, a mass of iron with a temperature of 3870°C. Although such temperatures would normally melt iron, immense pressure on it keeps it in a solid state. The inner core is approximately 2400 km in diameter.

Next is the **outer core**, a layer about 2200 km thick surrounding the solid inner core. It is slightly cooler than the inner core, yet still hot enough to keep the iron it is made of molten.



Around the core is the **mantle**, a rock layer about 2850 km thick that reaches about half the distance to the centre of the Earth. Parts of this layer become hot enough to liquefy and become slow moving molten rock called magma.

The outside layer of the Earth is the **crust**, a layer of rock varying from 12 km thick under the oceans to 100 km thick under mountains. The rocks and minerals we are familiar with on the surface are unique to the crust, which has a different chemistry to the mantle.

When scientists look at convection in the Earth, they see that the outer layer is very rigid. This rigid layer is about 100 km thick and is the crust and the top of the upper mantle. Called the **lithosphere**, it is this layer that has broken and cracked making the tectonic plates. Convection in the mantle causes these tectonic plates to move sideways over the surface of the Earth. Sometimes the tectonic plates collide into each other, crumpling and folding and forming mountains, volcanoes and earthquakes, all evidence of the active, changing Earth.

2 ACTIVITY QUESTIONS

1. Record your observations during the convection experiment. Draw and label a picture showing the movement of the food colouring when heated.

   Title:

2. What is the movement of the heated liquid called? Describe the process.

3. In a brief paragraph, explain how convection affects the Earth's tectonic plates.

4. List the layers of the Earth starting from the centre.

5. What causes the constant movement in the Earth's mantle? Why can't we feel this movement?

6. Write definitions for the following terms.

inner core

outer core

mantle

lithosphere

magma

lava

convection

3 EARTHQUAKES

MATERIALS

- Figure: *Tectonic plates with Earthquake overlay* (Displayed on available classroom projection technology)
- Folded Rock Photos from the CD
- Handout: *KWL Chart*
- Handout: *1.3A Earthquakes Information Bulletin*
- Handout: *Earthquakes Activity*
- Handout: *Map of the world*
- 80 grit sandpaper – 28 cm x 23 cm ~11″ x 9″ (2/ group)
- A block of wood – 28 cm x 5 cm x 11 cm ~ 11″ x 2″ x 4″ (1/ group)
- Rubber bands (2/group)
- Tack (1/group)
- Ruler or measuring tape

Consumables:
- Masking tape
- Coloured pencils

SUMMARY OF TASK

Students will:

- Explain the causes of natural events that occur on or near the Earth's surface (e.g. earthquakes).

EARTH SCIENCE LITERACY PRINCIPLE(S)

BIG IDEA 3 Earth is a complex system of interacting rock, water, air, and life.

BIG IDEA 4 Earth is continuously changing.

BIG IDEA 8 Natural hazards pose risks to humans.

OBJECTIVES

1. Demonstrate through the use of mapping techniques that earthquakes occur along the boundaries of the Earth's tectonic plates.
2. Investigate the relationship between earthquakes and tectonic plates.
3. Describe the process that causes earth displacement and earthquakes.
4. Participate in an experiment/demonstration of energy release.

INSTRUCTIONS

Engage

1. Introduce the topic of earthquakes through the use of a Know-Wonder-Learned (KWL) Chart graphic organiser.
2. Ask students what they already know about earthquakes, then write questions about what they wonder (or want to learn) about earthquakes.

Explore

3. Students carry out Earthquakes Activity A: Model of an Earthquake, an experiment that provides a clear visual of how the concepts of displacement, **seismic activity**, **friction** and **elastic** energy work together to cause earthquakes.
4. Students will take notes including materials used, the process and the result using the proper scientific method procedures.
5. Students carry out Earthquakes Activity B: Mapping Earthquakes.

Explain

6. Students complete the final column of their handout: *KWL Chart,* describing the motion of the wooden block during the experiment, and relating it to movement on plate boundaries that causes earthquakes, using handouts: *Earthquakes Information Bulletins 1.3A and 1.3B*

Elaborate

7. Students answer the questions on handout: *Earthquakes Activity* using the information that they plotted on the map and the map of tectonic plate boundaries.
8. As a class, review the information contained in the first paragraph of handout: *Earthquakes Information Bulletin.*

9. Visit the online animation "This Dynamic Planet" from the Smithsonian Institute Global Volcanism Program http://volcano.si.edu/learn_dynamicplanet.cfm.
10. Use the Figure: Tectonic Plates with Earthquake overlay to summarize how most of the Earth's seismic activity happens along plate boundaries.
11. Have students monitor the news reports for earthquakes around the world for a period of time (2-3 weeks) then place these occurrences on the world map (by magnitude and date). Alternately students can collect that data for the same time period using the IRIS Seismology in Schools website https://www.iris.edu/hq/sis.

Evaluate

12. At the end of the session, provide each student with an index card and have them complete a response to the Exit Question: What is the most important information about earthquakes that you think someone living in Canada should know? Use their responses to measure understanding of the concepts presented.

SUPPORTING INFORMATION

The Activity provides a model of how the two sides of a fault stick together when pushed. The stored energy builds up along the fault until the pushing force exceeds the frictional force between the two pieces of rock. There is a sudden release of energy, resulting in the two plates slipping past each other.

Key Words:

Basic Terms: subduction zones, seismic activity, displacement, fault line, earthquake, friction, elastic, focus, epicentre, body waves, primary wave, secondary wave, magnitude

Secondary Terms: collision, brittle, Richter scale, seismic, seisometer, seismic wave

SAFETY

- Have students keep track of the tacks that are provided and return them at the end of the lesson.
- Elastic bands should only be used as described in activity instructions.

3 KWL CHART

Topic: ______________________________

What I Know	What I Wonder	What I Learned

EARTHQUAKES

Think about how you might spend an ordinary day at home. Maybe, you're watching TV, reading a book or having some lunch. All of a sudden, things start to shake, dishes fall out of the cupboards, furniture topples over, the light from the ceiling crashes to the floor. It's an earthquake! The noise is tremendous. Suddenly, it's over. You look around at the damage and begin to wonder what happened?

The surface of the Earth consists of tectonic plates. These plates slide by each other along boundaries. The plates move past each other very slowly and steadily, perhaps moving only a couple of centimetres a year. However, some sections of the plates stick at certain points and are unable to move past each other. Resistance between the two stuck sections of the plates increases and energy builds up.

Although rocks appear to be solid and unbreakable, they are actually very flexible and can store energy much like a rubber band and release this energy in a sudden motion. Eventually, this energy is released and causes **displacement**. This means that there has been a movement in the Earth. A direct result of displacement is an earthquake. An **earthquake** is sudden shaking that has been caused by movement or volcanic activity within the Earth.

When earthquakes happen, the release of energy can be tremendous. Earthquakes vary in size and level of destructive force. Some events happen without being felt, while others continue for a number of seconds, with many aftershocks and affect a large area. Earthquakes occur in a number of areas around the world, including those that sit on top of tectonic boundaries. Many of these areas are heavily populated so understanding how an earthquake happens is important to those who study and attempt to reduce damage from these events, as well as to those who live with the possibility of experiencing an earthquake. Earthquakes can be very serious seismic events. These dramatic natural events are excellent examples of the dynamic and powerful nature of the Earth's crust.

Sources:

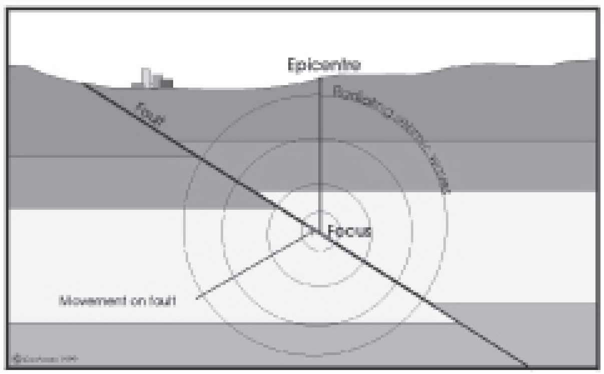
http://www.earthquakescanada.nrcan.gc.ca/index-eng.php
An excellent site for Canadian earthquake information and links to other sites.

http://www.discoveryeducation.com//teachers/
Lesson plans about earthquakes and related subjects.

(Be advised, you may need to create an account with Discovery Education to have full access)

EARTHQUAKES - TERMINOLOGY AND TECHNOLOGY

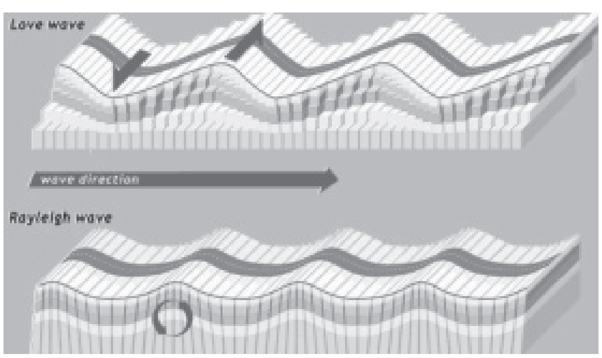
An earthquake occurs when there has been a release of stored energy within the earth's crust. Earthquakes take place along fault lines and when they happen they trigger a number of events. To understand these events and the accompanying results some terms need to be understood.



When an earthquake occurs there is a point at which a break or rupture begins deep inside the earth, this is called the **focus** of the earthquake. When the stored energy along the fault line is released, it spreads out from the focus like a wave. The shaking movement that occurs during an earthquake results from the passage of the waves that move through the earth from the focus.

When the waves move deep inside the earth they are known as **body waves**. The first type of wave is the fast moving P-wave or **primary wave**. These waves are commonly referred to as Push-Pull waves. Imagine a stretched Slinky lying on the ground. Hold one end in place and pull and push the other end of the Slinky in and out like an accordion. The waves that travel up and down the Slinky act like P-waves. The second type of wave is the S-wave or **secondary wave**, which travel more slowly but are more powerful and destructive. These waves shake the ground back and forth perpendicular to the direction in which the wave is moving. Picture the up and down hills of a roller coaster.

There are also two types of waves that occur at the surface of the earth. The first type of wave is the Rayleigh wave, which move the surface of the earth around in a circle, forward and down then back and up. This is the same as the motion in an ocean wave. The second type of wave is the Love wave, which moves in a circular fashion such as when you rub lotion on your skin. This shakes the surface of the earth side to side. These waves move more slowly than P-waves or S-waves but are more destructive, especially Love waves, which are often responsible for the collapse of buildings during an earthquake.



In order to better understand how earthquakes work, instruments to measure earthquakes have been developed. A *seismometer* measures the shaking caused by an earthquake by recording the ground movements. The *Richter scale*, which was developed by Dr. Charles Richter, is used to compare the *magnitude* of earthquakes. The magnitude is calculated by using several seismometers to measure the maximum amplitude of the waves and applying corrections for distance to the **epicentre**, which is the location on the surface of the earth directly above the focus of the earthquake. The Richter scale is open-ended, with common values in the range 1 to 9, but the scale is not even. Each number is 10 times as powerful as the last. For example, a magnitude 6 earthquake is 10 times greater than a magnitude 5 earthquake. It is important to understand that the Richter scale measures the magnitude of shaking, not the total energy released. A one point increase in the Richter scale value equals approximately a 32 times increase in the earthquakes energy.

RICHTER SCALE MAGNITUDE AND TYPE OF DAMAGE
Value: Type of Damage

1 - 2:	Movement recorded on local seismometers, but generally not felt.
3 - 4:	Often felt, but generally no damage.
5:	Felt widely with slight damage near the epicentre.
6:	Damage to poorly constructed buildings/structures within 10 km of the epicentre.
7:	Major earthquake; causes serious damage up to 100 km from the epicentre.
8:	Great earthquake; causes great destruction and loss of life over several 100 km.
9:	Rare great earthquake; causes major damage over a large region of 1000 km.

Sources:
http://www.earthquakescanada.nrcan.gc.ca/index-en.php
Up to date information on Canadian earthquakes and related events.

MATERIALS

- 2 pieces of 80 grit sandpaper - 28 cm x 23 cm sheet (11” x 9”)
- A block of wood approximately 28 cm piece of 5 cm x 10 cm (11” piece of 2x4)
- 2 rubber bands (1 thick and 1 thin)
- A tack
- Masking tape
- Metre stick or measuring tape
- Information Bulletin – Earthquakes
- KWL Chart

A. Model of an Earthquake

PROCEDURE:

1. Attach one piece of 80 grit sandpaper to the top of a desk with the rough side facing up. Use masking tape to secure the edges of the sandpaper to the desk. Place the ruler or measuring tape alongside the sandpaper.
2. Wrap the other piece of 80 grit sandpaper (rough side out) around the sides of the wooden block. Use the thick elastic band to secure the sandpaper around the sides
3. Push a tack into one end (not the top and bottom) of the wood and tie the thin elastic band to the tack.
4. Place the sandpaper covered wooden block at one end of the sandpaper attached to the desk.
5. Slowly pull on the wooden block with the elastic band measuring the length of the elastic in 1 cm intervals.

   Notice how the force of your pulling builds up in the elastic band causing it to stretch while the block remains in place. The elastic continues to stretch until the force exceeds the friction between the two pieces of sandpaper and the wooden block moves in a sudden jerking motion.
6. Record the stretch length at which the block moves and measure the displacement that occurs between the block and the sandpaper.
7. Repeat several times and compile data.
8. Read Earthquakes - Information Bulletins 1.3a amd 1.3b. On the final column of your KWL Chart then complete the third column stating what you learned about the contribution of the movement of the tectonic plates to earthquake occurrence.

MATERIALS

- Map of the world
- Table of major earthquakes
- Colored pencils
- Map of the Tectonic Plates (from lesson on Tectonic Plates)

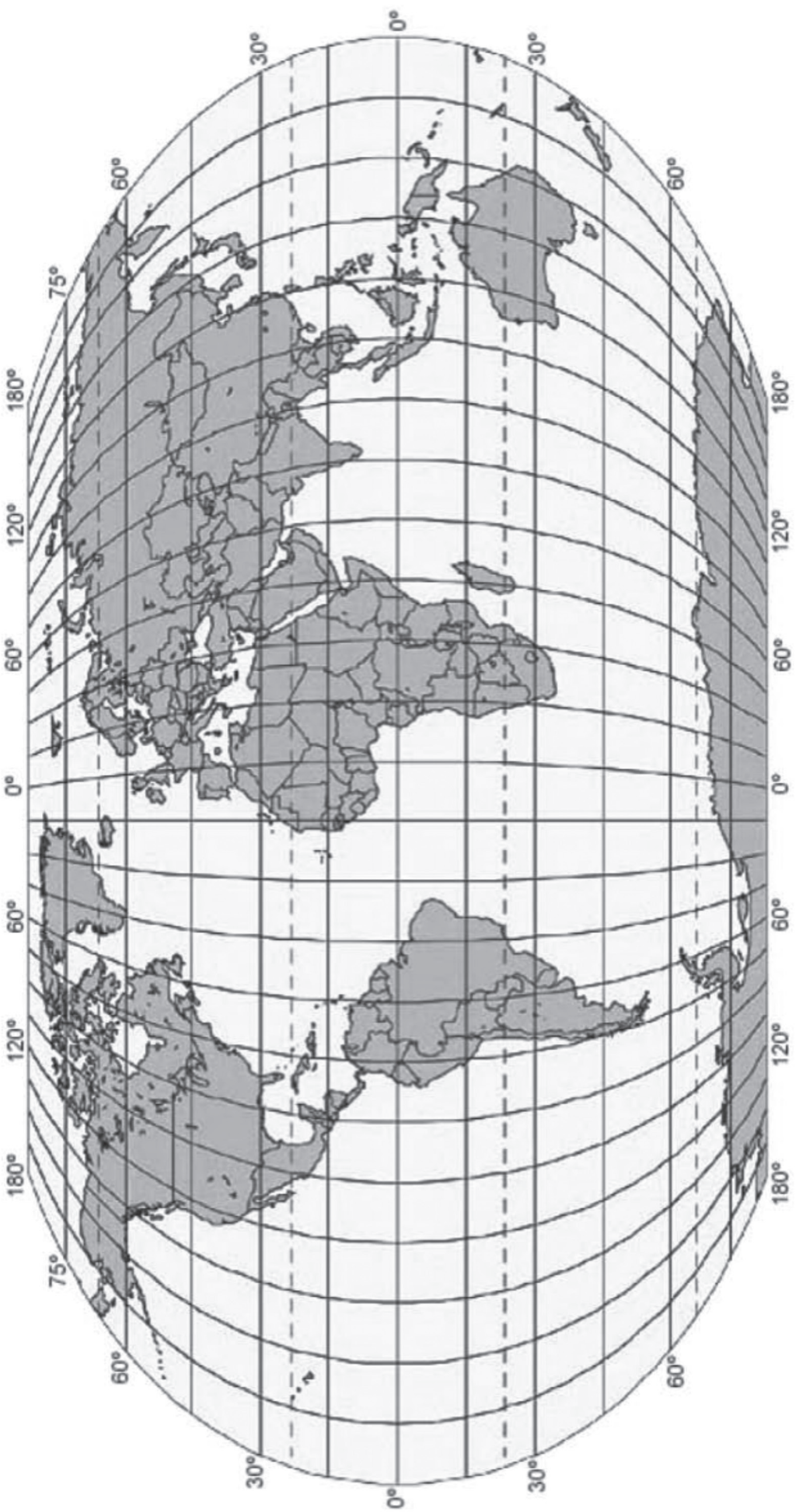
B. Mapping Earthquakes

PROCEDURE:

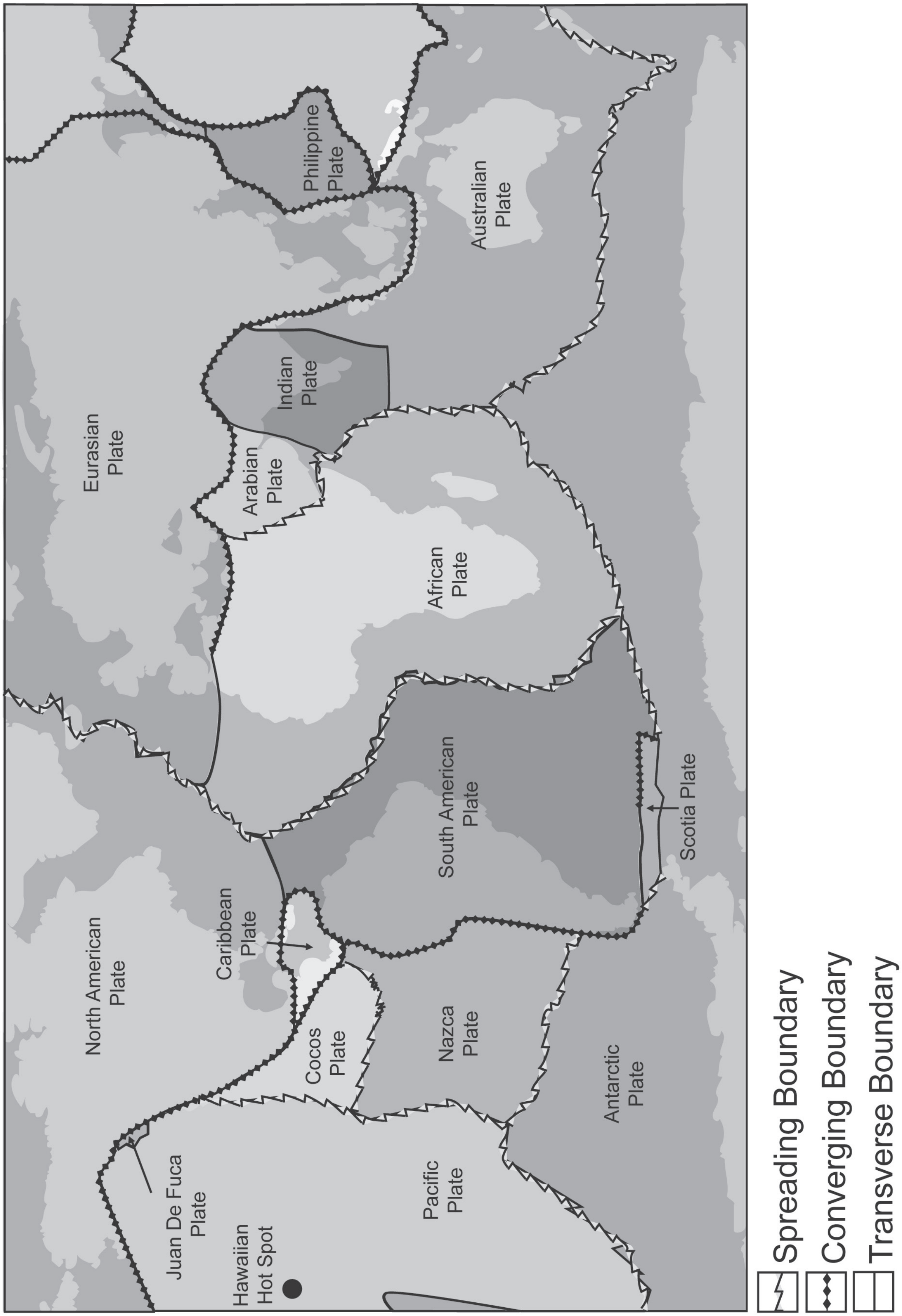
1. On the map of the world, and using the data table provided, find the location of the earthquakes.
2. With a colored pencil, mark a star on the map at the location of all 16 earthquakes. Remember that longitude marked is across the top and latitude is marked along the side of the map.
3. Based on your map of earthquakes and the map of tectonic plates, answer the following:
   a. Where are most of the major earthquakes in relationship to the tectonic plates?
   b. Are there any major earthquakes not located on the edge of a tectonic plate?

DATA TABLE: MAJOR EARTHQUAKES

EARTHQUAKES	LOCATION	LONGITUDE	LATITUDE
1	China	110E	35N
2	India	88E	22N
3	Pakistan	65E	25N
4	Syria	36E	34N
5	Italy	16E	38N
6	Portugal	9W	38N
7	Chile	72W	33S
8	Chile	75W	50S
9	Equador	78W	0
10	Nicaragua	85W	13N
11	Guatemala	91W	15N
12	California	118W	34N
13	California	122W	37N
14	Alaska	150W	61N
15	Japan	139E	36N
16	Japan	143E	43N


0°
30°
60°
75°
180°
120°
60°
0°
60°
120°
180°
75°
60°
30°
0°
30°
60°
180°
120°
60°
0°
60°
120°
180°
60°
30°

Print overlay on on acetate (transparent film)


Eurasian Plate
Philippine Plate
Australian Plate
Indian Plate
Arabian Plate
African Plate
South American Plate
Scotia Plate
Caribbean Plate
North American Plate
Cocos Plate
Nazca Plate
Antarctic Plate
Pacific Plate
Juan De Fuca Plate
Hawaiian Hot Spot
Spreading Boundary
Converging Boundary
Transverse Boundary

4 VOLCANOES – THE RUMBLINGS WITHIN

MATERIALS

- Figure: *Tectonic plates with overlay Areas of Volcanic Activity* (Displayed on available classroom projection technology)
- *Violent Hawaii Full Documentary* Available here: https://www.youtube.com/watch?v=n_IUIW8--Ak
- Handout: *KWL Chart*
- Handout: *The Rumbling Within Information Bulletin*
- Handout: *The Rumbling Within Activity A*
- Handout: *The Rumbling Within Activity B*

SUMMARY OF TASK

Students will:

- Explain the causes of natural events that occur on or near the Earth's surface (e.g. volcanic eruptions).

EARTH SCIENCE LITERACY PRINCIPLE(S)

BIG IDEA 3 Earth is a complex system of interacting rock, water, air, and life.

BIG IDEA 4 Earth is continuously changing.

BIG IDEA 8 Natural hazards pose risks to humans.

OBJECTIVES

1. View and comment on the video segment "Violent Hawaii" (Up to 15 min.:50 sec.).
2. Read Information Bulletin and answer questions.

INSTRUCTIONS

Engage

1. Introduce the topic of volcanoes through the use a handout: *KWL Chart.*
2. Have students complete the first two columns: what do they know and what would they like to know about volcanoes.

Explore

3. The class will view a 5 minute video segment *"Violent Hawaii" (Up to 15 min.:50 sec.)* showing footage of volcanic activity and lava flow in Hawaii.
4. After viewing the video segment ask the students for descriptive words about the film they have viewed. These answers may be written down on the board, or overhead. Ask the students what effect volcanoes have on the surrounding physical environment and on both the human and wildlife populations.

Explain

5. Hand out the handout: *The Rumblings Within Activity A*. This activity is a continuation of the handout: *Earthquakes Activity B: Mapping Earthquakes* from Activity 1.3. The completed earthquake map will be needed to plot the volcanoes on and help answer the questions that follow this activity.
6. Share the Figure: Tectonic Plates with overlay Areas of Volcanic Activity. Revisit the overlay Earthquake Zones from Activity 1.3. Review student responses to the questions in Activity A. The Rumblings Within.
7. Hand out the handouts: *Information Bulletin* and *Volcanoes – The Rumblings Within Activity Sheet B.*
8. Students will use the information bulletin to complete the chart on volcano types in handout: *The Rumblings Within Activity B.*

Elaborate

9. Explain to the students that while the basic process by which volcanoes erupt is the same for all volcanoes, not all volcanoes are the same. Divide the class into pairs or groups, with each pair/group at their own computer.

Direct the student pairs/groups to the Virtual Volcano Fieldtrips website (http://volcano.oregonstate.edu/fieldtrips) where they will join a team of volcanologists as they explore and photograph the worlds volcanic areas.

Evaluate

10. In small groups, have students compare their responses in the chart "The Rumblings Within Activity B." Identify any differences, and clarify responses based on material in the lesson. Students make amendments as needed to their charts.
11. Have students collaborate to complete the final column of the KWL chart with information learned about volcanoes.

SUPPORTING INFORMATION

Key Words:

Basic Terms: lava, magma, shield volcano, cinder cone, composite volcano, crater, vents, volcano, volcanism, conduit system

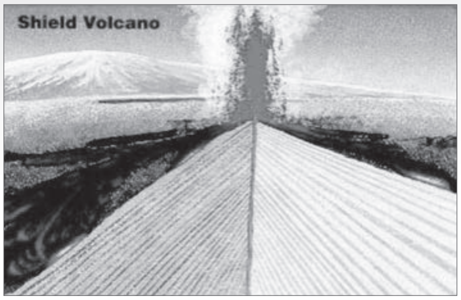
Secondary Terms: caldera, fumaroles, volcanologist, volcanic mountain, stratovolcanoes, tephra

4 KWL CHART

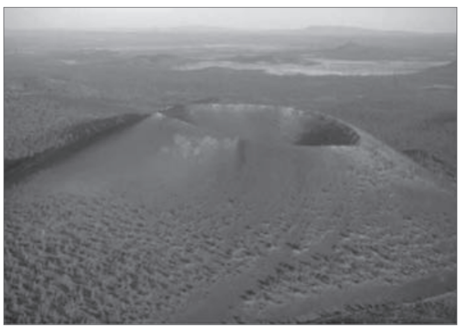
Topic: ______________________________

What I Know	What I Wonder	What I Learned

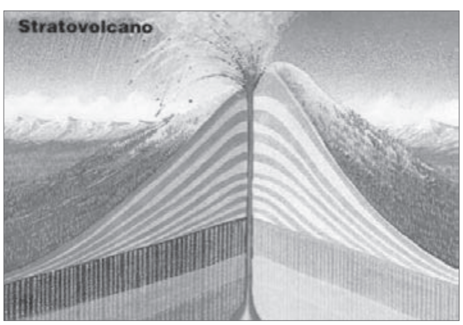
THE RUMBLING WITHIN



Volcanoes result from one of the world's most powerful natural forces shaping our dynamic Earth. A **volcano** is a vent or fissure through which molten and solid materials and hot gases pass upward to the Earth's surface. There are three different types of volcanoes. **Shield volcanoes**, the largest type of volcano, are built almost entirely of solidified **lava** flows. The lava, which is molten rock that flows down the side of the volcano, erupts through **vents** or openings that develop along the sides and base of the volcano. Thousands of highly fluid lava flows spread over great distances and cool in thin sheets. This builds a gently sloping cone. Some have compared it to a warrior's shield, and therefore the name of shield volcano. Hawaiian volcanoes are examples of shield volcanoes.



The next type of volcano is a **cinder cone** (or tephra cone). They are the simplest type and often the smallest. They are formed when lava is quickly expelled from the main vent of the volcano. Gas dissolved in the lava blows it into the air and the lava solidifies into small fragments that fall as cinders/tephra around the outside of the vent and form a circular cone. Most cinder cones have a well formed bowl-shaped **crater** at the summit of the volcano. Cinder cones range in size from 10 to several hundred metres high. There are many examples of cinder cone volcanoes along the western coast of North America, like Mount Shasta in California and Sunset Crater in Arizona.



The third type of volcano is a **composite volcano**. These volcanoes, sometimes also called *stratovolcanoes*, are typically steep, symmetrical cones of large dimensions that have been built from alternating layers of lava flows, cinders, ash and other volcanic material. A central vent is located within the crater at the top of the volcano. One of the essential features of a composite cone is a **conduit system** through which **magma** rises to the top of the volcano from an underground reservoir deep in the earth's crust. With each eruption, the cone grows larger. Some composite volcanoes reach heights of 2,800 metres. Mount St. Helens is an example of a composite volcano.

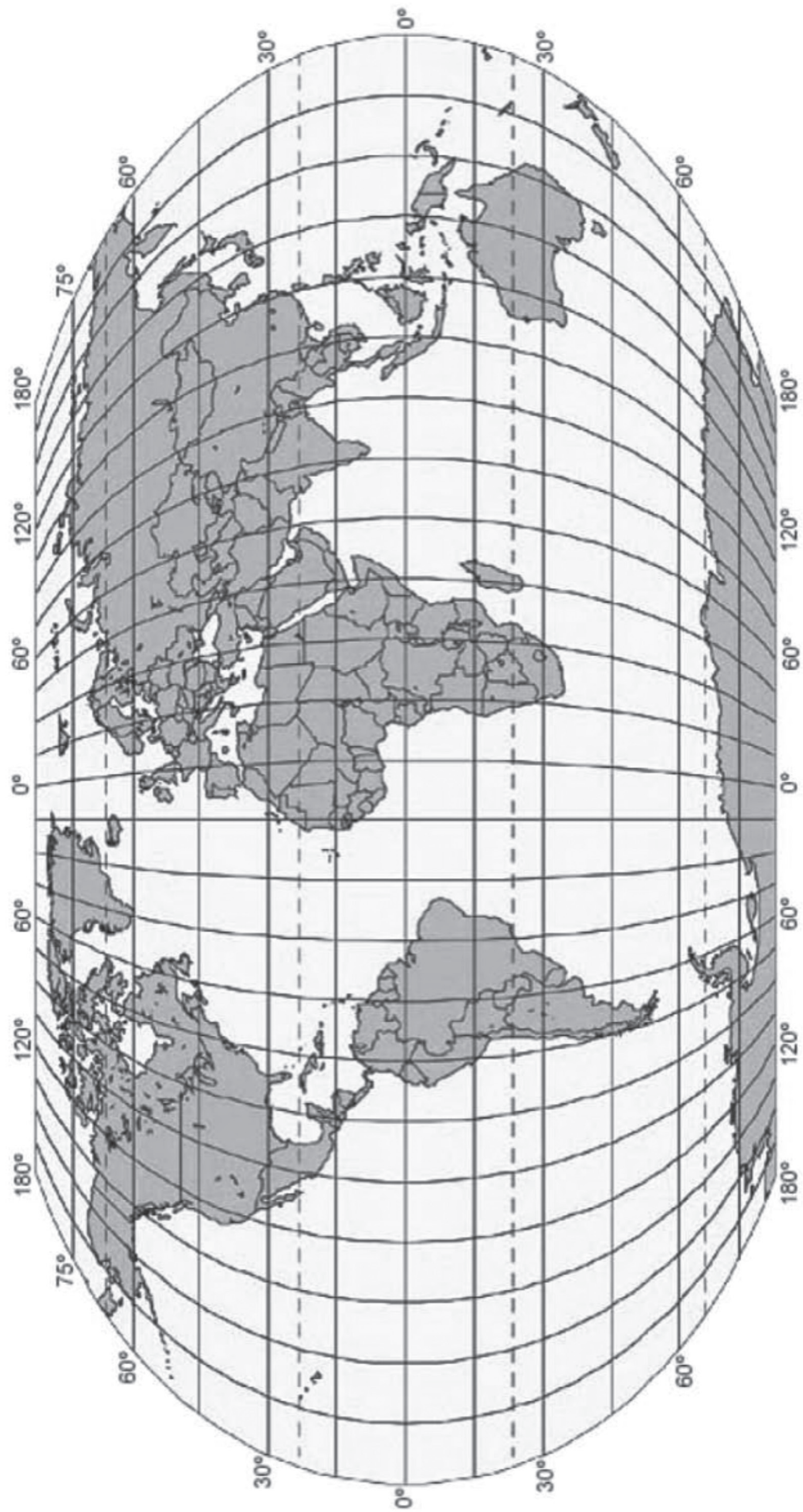
There are many more volcanoes beneath the surface of the sea than we can see on land. Volcanoes on the seafloor build cones from the ejection of lava and *tephra* just like volcanoes on land but submarine eruptions are different in two ways – the composition of the lava is not the same and the pressure of the seawater results in the creation of some products not found on land. Submarine **volcanism** creates new islands. One of the world's newest islands is Surtsey which first formed in 1963, just off the south coast of the island of Iceland in the Atlantic Ocean.

Sources:

http://pubs.usgs.gov/gip/volc/types.html
Good site for describing various types of volcanoes.

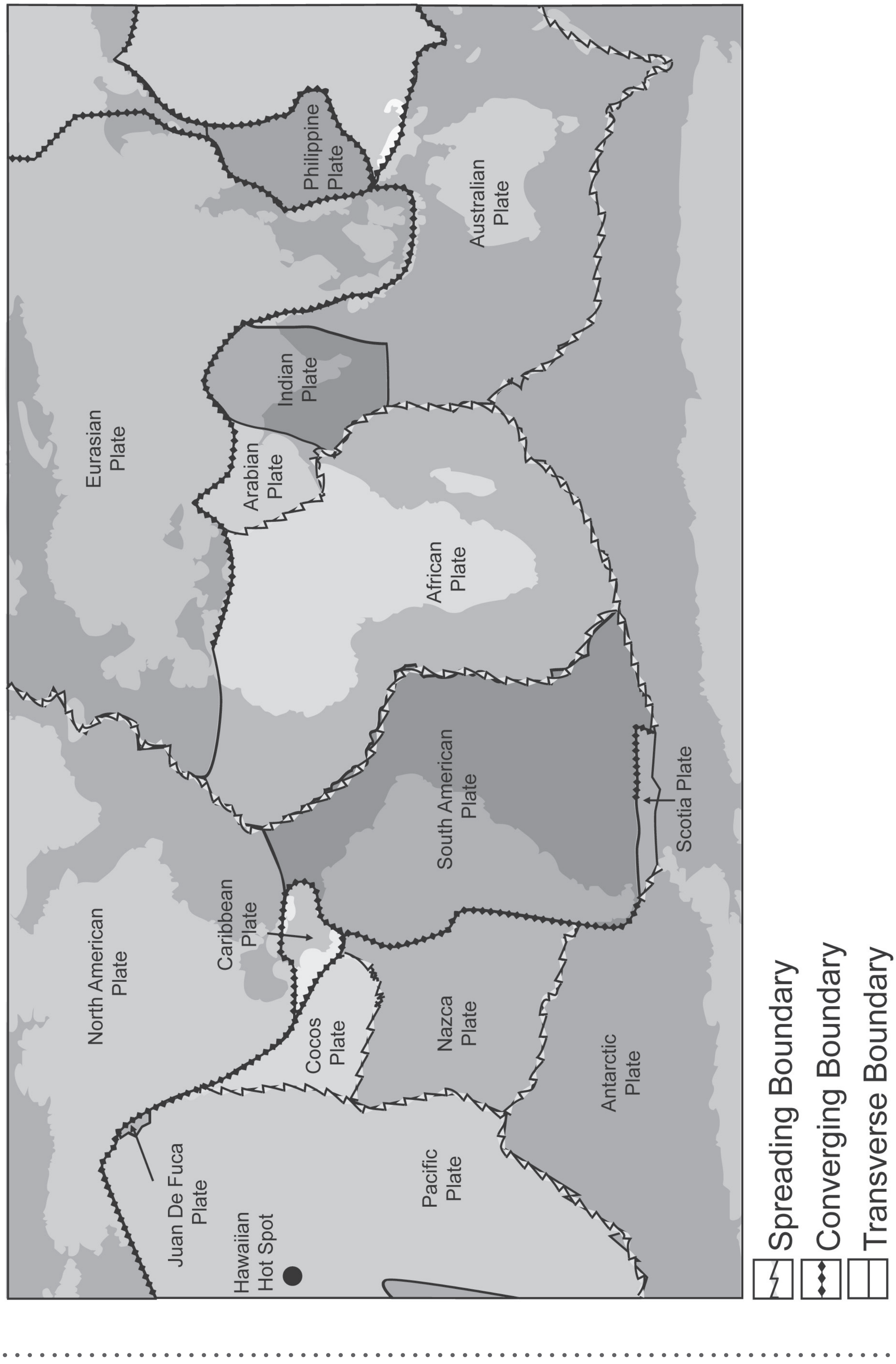
http://www.learner.org/interactives/dynamicearth/index.html
General information to support volcano lessons.

MAP OF THE WORLD



OVERLAY - AREAS OF VOLCANO ACTIVITY

Print overlay on on acetate (transparent film)


Philippine Plate
Australian Plate
Indian Plate
Eurasian Plate
Arabian Plate
African Plate
South American Plate
Scotia Plate
North American Plate
Caribbean Plate
Cocos Plate
Nazca Plate
Antarctic Plate
Juan De Fuca Plate
Pacific Plate
Hawaiian Hot Spot
Spreading Boundary
Converging Boundary
Transverse Boundary

MATERIALS
- Map of the world
- Table of major volcanoes
- Colored pencils
- Map of the tectonic plates (from lesson 1.1 Tectonic Plates)

A. The Rumblings Within

In this activity you will locate where some of the major volcanic activities have occurred. You will examine the relationship between the location of these volcanoes and the lithospheric plates.

PROCEDURE:

1. Using the data table provided, find the location of the volcanoes on the map.
2. With a colored pencil (a different one than already on the map), mark a triangle on the map at the location of all 17 volcanoes. Remember that *longitude* is marked across the top and *latitude* is marked along the side of the map.
3. Compare the locations of the volcanoes to the location of the earthquakes that you plotted on your map.
4. On a separate sheet of notebook paper, copy and answer the questions listed below
   a. Which ocean has a ring of volcanoes around it?
   b. Where are most of the volcanoes located in relationship to the tectonic plates?
   c. Which volcanoes are not located on the edge of a tectonic plate? What might account for the location of these volcanoes?
   d. What is the relationship between the location of the major volcanoes and the location of the major earthquakes?

VOLCANOES	NAME	LONGITUDE	LATITUDE
A	Aconcagua	70W	35S
B	Tungurahua	80W	0N
C	Pelee	61W	15N
D	Tajumulco	90W	15N
E	Popocatepetl	100W	20N
F	Lassen	122W	40N
G	Rainier	122W	47N
H	Katmai	155W	60N
I	Fujiyama	139E	35N
J	Tambora	120E	10S
K	Krakatoa	108E	5S
L	Mauna Loa	155W	20N
M	Kilimanjaro	37E	3S
N	Etna	15E	38N
O	Vesuvius	14E	41N
P	Teide	16W	28N
Q	Laki	20W	65N

B. The Rumblings Within

Use the information contained in the Information Bulletin to complete the chart:

	Shield Volcano	Cinder Cone Volcano	Composite Volcano
Size			
Composition			
Method of formation			
Interesting fact(s)			
Sketch			

5 FOLDING AND FAULTING

MATERIALS

- Figure: *Folding and Faulting* (Displayed on available classroom projection technology)
- Folded Rock Photos from www.sciencephotos.com or search the World Wide Web for free images to use as examples
- Handout: *Compare and Contrast Chart*
- Handout: *Folding and Faulting Information Bulletin*
- Handout: *Folding and Faulting Activity (A1 and A2)*
- Fishing line with a washer tied to each end ("cutting device")
- Small, transparent, plastic box
- Cardboard to fit tightly in box

Consumables:

- Play-Doh (or plasticine)
  - 4-6 different colours
- Popsicle sticks
- Sand
- Flour
- Chocolate powder

SUMMARY OF TASK

Students will:

- Explain geological processes and events using the theory of plate tectonics.

EARTH SCIENCE LITERACY PRINCIPLE(S)

BIG IDEA 3 Earth is a complex system of interacting rock, water, air, and life.

BIG IDEA 4 Earth is continuously changing.

OBJECTIVES

1. Model folding and faulting using "Playdoh," sand and flour, and popsicle sticks.
2. Complete the *Compare and Contrast Chart* on folding and faulting.

INSTRUCTIONS

Engage

1. Show students some pictures of highly defined folds and ask them to think of ways they could have formed. Remind them of the characteristics of rocks (hard, brittle, rigid, etc.).
2. Have them visualize some of their suggestions and predict what patterns they might expect.

Explore

3. Distribute handout: *Folding and Faulting Activity (A1 and A2)* – these are best done as hands-on activities for groups of students, but may also be a demonstration.
4. Have students work through activity A1, observing how Play-Doh bends and the popsicle stick breaks.
5. Read through the handout: *Folding and Faulting Information Bulletin* with the class, having them highlight the important information.
6. Have students work through activity A2: Play-Doh faults, modelling and sketching the three types of faults.

Explain

7. Present Figure: *Folding and Faulting* and discuss with the class the new terms related to folding and faulting.

Elaborate

8. Have students work through activity A3: Geological Squeeze Box: Folds and Faults, drawing a sketch and answering questions on the activity sheet.
9. Look back at the folded rock photos and have the students explain how these patterns were caused.

Evaluate

10. Have students complete handout: *Compare and Contrast Chart* for folding and faulting.
11. Visit, http://www.teachingboxes.org/mountainBuilding/resources/indexbox.jsp, search the online resources and lessons section for the Mountain Photo Archive pdf file. Observe and discuss which mountains appear to be made of folded layers.

SUPPORTING INFORMATION

Folded mountains are formed as the result of compression or squeezing of the Earth's surface. These forces cause the rocks to bend (fold) and break (faulting). If the compression exceeds the rock's strength and it can no longer withstand the strain, it will break. One result of this is large blocks of the Earth's crust riding up and over the top of adjacent blocks in a process called thrust faulting.

Key Words:

Basic Terms: strata, sedimentary, fold, fault, anticline, syncline, normal fault, reverse fault

Secondary Terms: compression, shearing, dip-slip faults, hanging wall, foot wall, strike-dip faults, folded mountains, fault block mountain

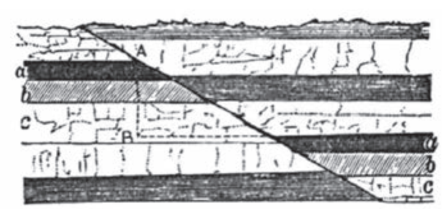
SAFETY

- When using the fishing line, students should be careful not to apply pressure to anything but the instructed material. Fishing line can be sharp.
- The popsicle stick will have sharp edges when broken. Handle by the un-broken ends only.
- Students should wash their hands thoroughly after handling sand and flour.

FOLDING AND FAULTING

The Earth is a dynamic planet and the enormous forces within the planet play a central role in forming the landscape we live in. Canada is home to spectacular land formations such as the Rocky Mountains and the Canadian Shield. In the last lesson we saw how tectonic activity (the movement of tectonic plates) can lead to violent upheavals in the form of mountains. In addition to this, as we have learned, tectonic forces deform rocks in the Earth's crust. The evidence for such activity is thousands of kilometres of rock layers that are bent, rumpled and fractured. The Earth's major mountain belts contain fossils of marine animals thousands of metres above sea level. Massive rock formations are folded as if they were made of modeling clay. These findings point to the tectonic activity forming the Earth's landscape. It is very important to study rock structures when we are selecting sites for bridges, hydroelectric dams, nuclear power plants and of course homes and communities. The knowledge of how a certain geographical area formed geologically – understanding the process of folding and faulting among others – allows us some understanding of the potential dangers of certain landforms.

Most rocks originally form in flat layers called **strata**. Some layers are **sedimentary**, which means they are created from rock particles (sand and mud) settling together. Others are volcanic, meaning there were formed due to volcanic processes. When these strata are compressed (squeezed), folding occurs. A **fold** is a bent layer, or series of layers, of rock that were originally horizontal and have become deformed (pushed out of shape). Folds come in different shapes and sizes from a few millimetres to tens of kilometres. The bending can be gentle or severe depending upon the amount of force. An arch shape fold is called an **anticline** and a down warp fold is called a **syncline**. Folding generally makes the rock units shorter and thicker.



Faults are fractures along which movement has occurred on either side of the crack. Faults can be caused by different forces such as *compression* (squeezing), *extension* (pulling) or *shearing* (tearing). Small faults consist of single breaks. Large faults, like the San Andreas fault in California, consist of many interconnecting faults. Sudden movements along faults are the cause of most earthquakes.

Faults in which the movement is mainly vertical are called *dip-slip faults* because the slip, or displacement, is parallel to the dip of the fault plane. The rock surface that is immediately above the fault is called the hanging wall and the rock surface below is called the footwall. These names have an interesting history, since they were given by miners who sometimes excavated tunnels along faults containing important minerals, such as gold. The miners would walk on the rocks below the fault (the *footwall*) and hang their lanterns on the rocks above (the *hanging wall*)! Dip-slip faults are classified as either *normal faults*, caused by pulling forces, where the hanging wall moves down relative to the footwall; or *reverse faults*, caused by squeezing forces, where the hanging wall moves up relative to the footwall.

Strike-slip faults are faults in which the movement along the fracture is horizontal, and parallel to the strike of the fault surface. Strike–slip faults result from tearing forces and generally consist of a zone of parallel fractures. The earliest records of strike-slip faulting were made after examining the surface ruptures produced by large earthquakes, such as the famous San Francisco Earthquake of 1906.

Folding and faulting have affected and continue to affect the landforms we find on Earth. Knowledge of folding and faulting has real importance for everyday life. It allows us to better understand the dynamic forces within the Earth that can be applied to decisions as to how and where we build our homes, communities, bridges and dams. It also helps us to know where to search for mineral and petroleum resources which sustain our economy.

A1: Folding and Faulting

Play-Doh Folds

1. Make a flattened pancake of each colour of Play-Doh (about 15 cm in diameter and 1 cm thick). The greater the diameter, the thinner the layers and the more easily the model can be folded.
2. Stack the layers on top of each other in any colour order to make a block.
3. Use colouring pencils that closely match the Play-Doh, sketch the side view of this model in the space labelled, **Diagram A**.
4. **To simulate compression -** place your hands, one on either end of the play dough block. Gently push your hands together so that you squeeze it along its longer axis. This will cause the play dough block to fold and buckle. Try to make at least one upward fold (anticline) and one downward fold (syncline)
5. Use colouring pencils that closely match the Play-Doh, sketch the side view of this model in the space labelled, **Diagram B**.
6. **To simulate surface erosion-**Take your cutting device (fishing line and washers) and cut the top off of your folded model.
7. Use colouring pencils that closely match the Play-Doh, sketch the side view of this model in the space labelled, **Diagram C**.
8. Discuss what you observe with your group members. Repeating bands of sedimentary layers, such as in this model, when found at the surface of the Earth tell a geologist that they have found an eroded fold.

Popsicle Stick Faults

1. Take one Popsicle stick. Hold it in both hands and bend it. What happens? Instead of folding, the Popsicle stick is brittle, and breaks. This is how a fault is produced in rocks.

A2: Play-Doh Faults

1. Cut your play dough block model in a vertical direction – add a little bit of an angle if you like.
2. Use this new model to demonstrate a normal fault, a reverse fault, and a strike-slip fault.
3. Use colouring pencils that closely match the Play-Doh, sketch the side view of this model in the space labelled, **Diagram D**.

Diagram A	Diagram B	Diagram C

Diagram D		
Normal Fault	Reverse Fault	Strike-Slip Fault

MATERIALS

- Transparent plastic box*
- Thick cardboard

Consumables:

A variety of substances of varying colour and similar particle sizes

- Sand
- Flour
- Chocolate powder

A3: Geological Squeeze Box: Folds and faults

1. Cut a piece of card to size to fit tightly and stand up in one end of the plastic container.
2. Pour in a thin (a few millimetres) layer of sand. Sprinkle a thin layer of flour on top of the sand. Continue to alternate layers of sand, flour, and chocolate powder until box is about one third full
3. Hold the piece of cardboard firmly and move it slowly and gently toward the opposite end of the box. Try to keep it vertical.
4. As the cardboard moves, watch the layers of sand and flour carefully to see what happens.
5. Stop moving the card when it is about halfway along the box.
6. Make a sketch of the side of the box identifying the folds and faults in the sand and flour layers.

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*For a visual reference visit:
http://www.earthlearningidea.com/PDF/Himalayas_in_30_seconds_final_071029.pdf

Instructions to build a more sophisticated model can be found at:
http://www.di-mac.com/Peg1.JPG
https://www.boreal.com/store/catalog/product.jsp?catalog_number=800302

Watch:
https://www.youtube.com/watch?v=t3T69vMK8OI

How to make :
http://www.exo.net/~emuller/activities/The_Squeeze_Box.pdf

Sketch

1. What causes similar compression to occur to the Earth's crust?

2. Where does this occur on the Earth's surface?

3. How does the model you made simulate the processes at work in the Earth?

5 COMPARE AND CONTRAST CHART

Theme: ______________________ **Topic:** ______________________

COMPARE
How are ______ and ______ alike?

CONTRAST
How are ______ and ______ different?

Write a statement to compare and contrast two terms, concepts or events.