Plates Going Places

Vocabulary

crust

lithosphere

mantle

outer core

inner core

plates

convection current

magma

divergent plate boundary

strike-slip (transform) plate boundary

convergent plate boundary

Learning Links

Language Arts: Participating in class discussions, writing paragraphs, following directions

Social Studies: Locating plate boundaries, locating various geographic features

Math: Interpreting a graph of the thickness of Earth's layers, observing the proportions of the layers to each other

Art: Drawing the interior of the Earth, constructing a model of the Earth's interior

Content Concepts

1. The Earth has a layered structure.

2. Its outer layer, the lithosphere, is broken into pieces called *plates*.

3. Convection currents in the mantle might be the cause of plate motion which results in earthquakes.

Objectives

Students will
— describe the structure of the interior of the Earth.
— name and identity the layers of the Earth.
— interpret a graph of the approximate thickness of the Earth's layers.
— observe a model demonstrating the layers of the Earth and its plates.
— relate earthquake epicenters to plate boundaries.
— identify 12 major plates of the Earth.
— demonstrate the motions of plates.
— observe a convection current.

Assessment

Shakequake, USA (a fictitious town), has many earthquakes. Use what you learned in this unit to explain possible causes of earthquakes in that particular area.

Activity One: What's Inside

Materials for the teacher
- A globe of the Earth
- Transparency made from Master 15, A Pizza the Earth
- Transparency made from Master 16, Graph of the Earth's Layers, colored according to the directions in 3 and 4 below
- Overhead projector

Materials for each student
- Worksheet made from Master 15, A Pizza the Earth
- Worksheet made from Master 16, Graph of the Earth's Layers
- Crayons or colored pencils
- Metric ruler

Procedure

1. Show the students the globe. Define the term diameter, then tell them that the Earth's diameter is about 12,760 km or about 7,900 miles. Put this distance in context by comparing it to a distance students are familiar with, such as the distance from their town or city to a distant, but familiar location.

2. Explore students' ideas about the inside of the Earth. Is it the same all the way to the center? Distribute art supplies and ask them to draw what they think the inside of the Earth is like, then write a paragraph describing the drawing. (This activity will help you to know what background they are bringing to the topic.)

3. Project the transparency of the transparency of Master 15, A Pizza the Earth, and distribute the matching worksheet.

a. Explain that the drawing is a model of the layers inside the Earth. Briefly describe each layer, and have students label the inner core, outer core, mantle, lithosphere, and crust as you speak.

b. Ask students to color each of the Earth's layers a different color. Color the area from the beginning of the lithosphere out to the surface yellow, then go over the outermost section with blue to indicate the crust. (The overlapping colors, which should produce green for the crust, will help students to understand that the crust is part of the lithosphere.)

con • vec • tion cur • rent

A convection current is a circular movement in a fluid in which hot material rises and cold material sinks.

lith • o • sphere

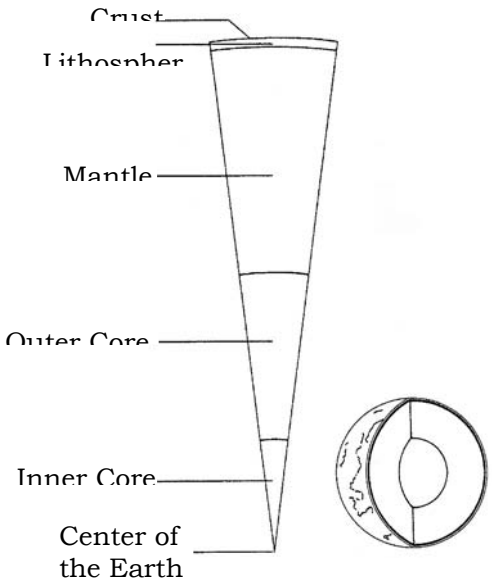
The lithosphere is the solid outer region of the Earth in which earthquakes begin. It contains the crust and the uppermost portion of the mantle.

out • er core

The outer core is the liquid portion of the Earth's core.

in • ner core

The inner core is the solid central portion of the Earth.



4. Distribute Master 16, Graph of the Earth's Layers. Ask students to use the following data to construct a bar graph of the thickness of the Earth's layers:

Layer	Thickness in Km
crust	40
lithosphere	100
mantle	2900
outer core	2000
inner core	1400

Remind students that a graph should contain a title, scale, and labels. Ask students to color each bar the same color they used for that layer in their Pizza of the Earth (Master 15) worksheet. Use a transparency of Master 16, Graph of the Earth's Layers, to discuss the proportions of the layers with your students.

5. (Optional) During another class period or as homework, invite students to make a three-dimensional model showing the layers of the Earth. Tell them they must label the layers and make them in correct proportion to one another. They may choose any material and manner of construction they like. You may want to display some of these models in a school display case.

Activity Two: We're All Cracked Up

Materials for the teacher
- Several hard boiled eggs
- Small kitchen knife
- Narrow permanent marker
- Free-flowing broad permanent marker

Teacher Take Note: **It may take several tries to cut the egg neatly. A very sharp knife will help.**

Procedure

1. Before class, cut a hard-boiled egg in half with its shell on. On one half, make a dot of color in the center of the yolk with a permanent marker to represent the inner core. Color the outside of the shell with the broad marker to represent the crust.

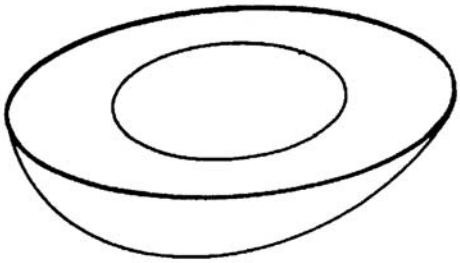
Rap another hard-boiled egg on any hard surface to produce a pattern of large cracks. When you have a design you like, outline the edges of the cracks with the narrow permanent marker. (This may also take several attempts. You do like egg salad, don't you?)

2. Use the marked half of the cut egg as a model to review the layers of the Earth with your students. Ask the following questions.

Which layer of the Earth does the shell represent? (The lithosphere. The color on the outside represents the crust, which is less than half as thick as the lithosphere itself.)

Which layer does the white represent? (The mantle)

Which two layers does the yolk represent? (The outer core and inner core)



Sliced, hard-cooked egg displays layers something like the Earth's. (So does an avocado, if you don't like cooking.)

3. Hold up a whole cooked egg and ask students what would happen to the shell if you rapped it on your desk. (It would develop cracks.)

4. Show them the cracked egg you prepared in advance and point out that the shell is now divided into adjoining sections. The lithosphere is similarly divided into sections, which we call *plates*. The plates of the Earth include a portion of the upper mantle as well as the crust. We use the term *lithosphere* to describe the part of the Earth to which the plates belong, from the surface down to a depth of about 100 km.

5. Explain that unlike the sections of eggshell, the plates of the Earth are in motion. They move very slowly (at a rate of only a few centimeters a year), over a portion of the mantle that has plastic properties, rather like the silicone putty or flubber we used in Unit I. This movement can cause earthquakes.

Cracked egg illustrates plates of the earth.

Activity Three: Plates of the Earth

Materials for the teacher

- Transparency of Master 17, Plate Boundaries Map
- Overhead projector

Materials for each student

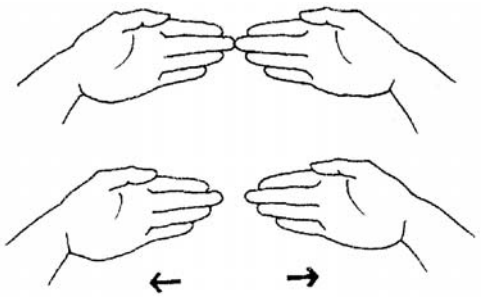
- Handout made from Master 7, World Map with Epicenters
- Handout made from Master 17, Plate Boundaries Map
- Crayons or colored pencils

Procedure

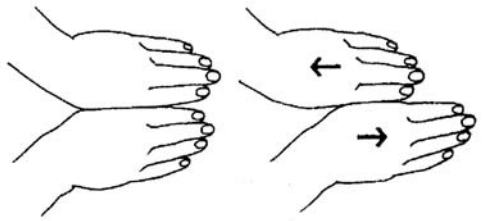
1. Distribute copies of the epicenter map and the plate boundaries map.

2. Ask students what relationship they see between the locations of earthquakes and the plate boundaries. They should be able to see a correlation.

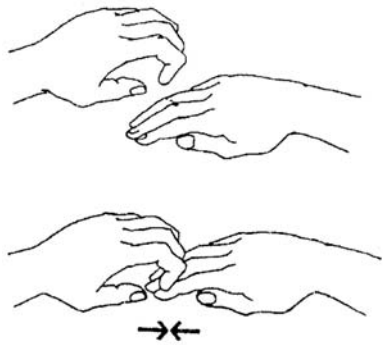
3. Point out the arrows on the Plate Boundaries Map, Master 17, which indicate the direction in which each plate is moving. Ask them to color the arrows red.



a. Divergent: Begin with fingertips and slowly pull hands apart



b. Lateral (transform): Begin with hands side by side. Slide one forward and the other back, so they pass by each other.



c. Convergent: Begin with knuckles facing each other. Bring hands together, letting one slide (subduct) under the other.

4. Explain that each plate has a name, and point each one out as you read its name aloud. Instruct students to put their red pencils or crayons aside and use different colors to color all of the plates—lightly, so the names and arrows can still be seen.

5. Either in a class discussion or on a worksheet followed by a class discussion, cover these points:

How many plates are there on the map? (Twelve. Explain that some experts identify twenty or more.)

Locate India. Where do you see a plate boundary in India? (on the northern border) What geographic feature do you find there? (mountains)

Locate the Atlantic Ocean. Are there any plate boundaries in that ocean? (Yes. Plate boundaries divide the ocean from north to south.)

Which large island in the Atlantic Ocean has a plate boundary going through it? (Iceland)

6. Project the transparency of the plate boundaries map.

7. Again point out the arrows which indicate plate movement, and explain that this movement is of three kinds: divergent, lateral (or transform), and convergent. Demonstrate hand motions to simulate each kind of movement, and practice them with the class as you give examples of each.

a. Divergent—Begin with fingernails pressing against each other, and slowly pull hands apart. Explain that this kind of plate movement is happening on the floor of the Atlantic and Pacific Oceans. As plates move apart, melted rock, or magma rises from the upper mantle to fill the spaces. Examples: South American plate and African plate; North American plate and Eurasian plate.

b. Lateral—Place hands side by side and slide them slowly past each other. Explain that this kind of activity is occurring right now along the San Andreas fault in California. Example: North American plate and Pacific plate.

c. Convergent—Start with hands facing each other and six inches apart. Bring them together so that one hand is forced under the other. The top hand should ride up and make a fist. Explain that converging plates may form high mountains such as the Himalayas.

As plates move together, one of the plates is pushed down (subducted) under the other: Examples: Australian-Indian plate and Eurasian plate, Nazca plate and South American plate.

Activity Four: Hot Stuff Rises and Cold Stuff Sinks

Materials for the teacher

- Clear heatproof glass baking dish, 23 cm x 13 cm x 7 cm
- Immersion heater (plug-in coil used to heat small quantities of water)
- Sandwich-size plastic bag with twist tie
- Tape
- 2 eyedroppers
- Red food coloring
- Blue food coloring
- A handful of solid paper circles from a hole puncher
- Ice cubes
- Cool water
- Transparency made from Master 18, Convection Currents and Plate Cross Section
- Overhead projector

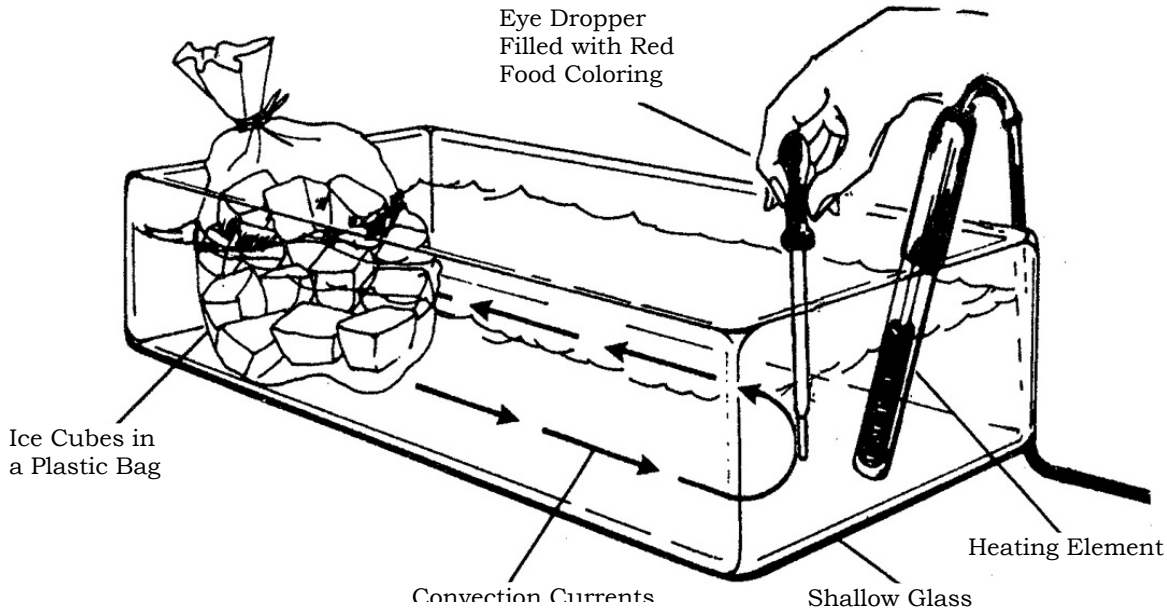
Procedure

1. Review the concept that Earth's lithosphere is broken into pieces called *plates*. Scientists believe that the plates move because of movement inside the mantle, the way groceries move on the conveyor belts in supermarket checkout lines. This demonstration illustrates what may take place.

2. Fill the glass baking dish almost completely full of cool water.

Teacher Take Note: **An immersion heater is safer than most other heat sources. You can buy one for $3-4 at most hardware stores. It is also a handy way to heat a cup of water for tea, coffee, or broth. A larger container, such as an aquarium, could be used for better viewing.**

Be sure to add the blue colored drops to the water just below the surface as drops on the surface will diffuse too quickly and not give the best effect.



Extensions

1. Read Joanna Cole's The Magic School Bus - Inside the Earth or Faith McNutly's How to Dig a Hole to the Other Side of the World as a class activity or make it an additional reading assignment.

2. Show pictures of Icelandic rifts, the San Andreas fault, the Himalayan mountains, and other physical features of the sort that occur at plate boundaries.

3. Show the class a film, filmstrip, video, or computer animation on plate tectonics. (Because most of them were designed for older students, you may want to show just portions, or use the images and provide your own narration.)

3. Put about six ice cubes in the plastic bag and close it with the twist tie.

4. Place the bag in the water at one end of the dish and tape it to the side so it can't float away.

5. Place the immersion heater in the water at the other end of the dish and plug it in. *Warn students to stay away from the heat source.*

6. Wait about one minute for the water to heat. Then use an eyedropper to put several drops of red food coloring on the bottom of the dish near the heater. Ask students to observe what happens. (Some of the coloring will rise to the top and float toward the other end of the dish.)

7. Now use the second dropper to put a few drops of blue coloring into the water just under the surface, near the ice. Ask students to describe what they see. (The coloring will sink and move along the bottom of the water toward the other end of the dish.)

8. Put a few of the paper circles on top of the water in the warm end. Students will see them moving around on the surface of the water. Explain that the Earth's plates may move on the semi-solid layer of the mantle in a similar way, because of temperature changes in the mantle. The systems of heat exchange that cause their movement are called convection currents. Hot material rises, while cold material sinks.

9. Project the transparency of Master 18, Convection Currents and Plate Movements, and point out that where two convection currents are rising together, the plates are forced apart. Where two currents are sinking together, the plates are forced together. Scientists hypothesize that these movements are the cause of many earthquakes.

10. If necessary, repeat the demonstration until all the students have had a chance to observe it at close range.

Layers, Plates, and Quakes

Vocabulary

crust
lithosphere
mantle
outer core
inner core
plate
strike-slip (transform) plate boundary
convergent plate boundary
divergent plate boundary
volcano
magma

Learning Links

Language Arts: Discussion, note taking, vocabulary building, following directions

Math: Using a scale to build Earth wedge model

Art: Drawing, cutting, and taping paper models; building convection model

Content Concepts

1. The Earth has a layered structure.

2. The Earth's outer layer is broken into pieces called plates.

3. Three basic kinds of movement take place at the edges of the plates.

4. Plate movements create special surface features near the edges of the plates.

5. Convection currents in the mantle may be the cause of plate movements.

Objectives

Students will

—make a model of the layers of the Earth.
—be able to describe the composition of the layers and their interrelationships.
—model and describe activity at the three major types of plate boundaries.
—observe a demonstration of convection currents and relate the process to plate movement.
—construct a model of continental movement from ancient time through the present and into the future.

Assessment

Shakemeup, USA (a fictitious town) is located on the coast of California. Scientists know that subduction is occurring under this part of California. Describe what you think will happen to this town over the next 100 years.

Activity One: Crust to Core: A Pizza the Earth

Materials for the teacher
- Transparency made from Master 15, A Pizza the Earth
- Overhead projector
- Transparency markers

Materials for each student
- 3 sheets of unlined paper, standard size
- No. 2 pencil
- Meter stick
- Tape
- Copies of Master 16, Graph of the Earth's Layer
- Copies of Master 15 (optional)

Procedure

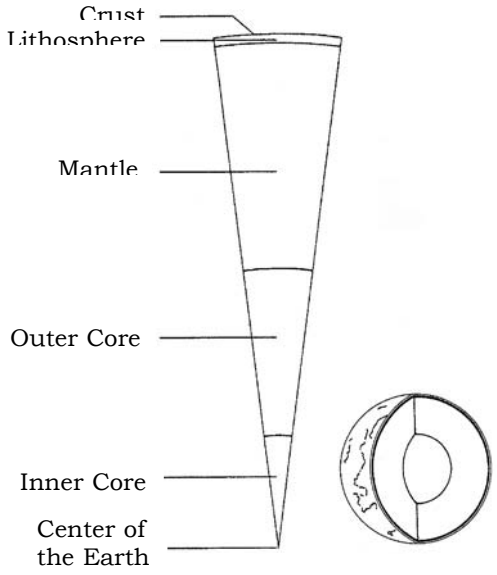
1. Elicit from class what they think the Earth is like below the surface. Accept various opinions. Depending on answers, class may need to use all or part of the first activity from Grades 3-4 in this unit.

2. Display the transparency of Master 15, A Pizza the Earth. Explain that the Earth is layered and that we have learned about these layers largely from the study of earthquake waves. Define *crust*, *lithosphere*, *mantle*, *outer core*, and *inner core* (see the lower-grade lessons in this unit), and ask students to write definitions of the layers in their notebooks for future reference. (Or give the students copies of Master 15, A Pizza the Earth, and have them add the definitions there.)

3. Tell the class that they are going to create a scale model of a slice of the Earth, from its surface to the center, using the following procedure:

a. Attach three pieces of unlined paper by taping together the shorter sides to make a strip about 80 cm long.

b. Turn paper over to the untaped side.



Master 15. A Pizza the Earth answers

"This Pizza the Earth sure has a thin crust."

mag • ma

Magma is liquid rock beneath the Earth's surface. When it erupts it is called lava.

vol • can • o

A volcano is a mountain of erupted hardened lava or volcanic rock fragments at the surface of the lithosphere.

Extensions

1. Research how scientists have discovered about the various layers of the Earth through the study of earthquake waves.

2. To the wedge model on Master 15 add the hydrosphere (average thickness of the oceans, about 3.8 km) and the atmosphere (about 960 km thick).

c. Draw, with the aid of a meter stick, a triangle 10 cm wide on top and 64 cm on its other two sides. (This is a scale of about one millimeter for each kilometer of the Earth's radius.) Label the 10-cm side **Earth's Surface** and the opposite end (the point of the wedge) **Center of the Earth**.

d. Compute the scaled distance from the Earth's surface to the bottom of each of the layers, using the data from Master 16. Graph of the Earth's layers. (Students will have to know the scale—1 millimeter equals 10 kilometers—and the definitions of the layers to be able to perform this task correctly. Be prepared to offer help as needed.)

e. Label the layers.

4. When the wedge models of Earth are completed, ask students to answer the following questions:

Which of Earth's layers is the thickest and accounts for most of its volume? (the mantle)

On which layer or layers are the plates? (lithosphere, or crust and upper mantle)

In which layer or layers can faulting occur to create an earthquake? (again, lithosphere or crust and upper mantle)

How does the part of the Earth we live on—the crust or lithosphere—compare in thickness to the Earth's interior? (It's the thinnest part.)

Activity Two: Slide, Collide, and Separate

Materials for the teacher
- Overhead projector
- Transparency made from Master 17, Plate Boundaries Map

Materials for each student
- Copy of Master 17, Plate Boundaries Map
- 10 sheets of lined notebook paper or other 8 1/2" x 11" sheets
- One sheet of colored construction paper
- Scissors
- Transparent tape
- Metric ruler

Procedure

1. Use the transparency and student copies of Master 17, Plate Boundaries Map, to explain that different types of interactions occur among lithospheric plates at their boundaries. You may want to use the hand movements from Level 2, Activity Three, of this unit to demonstrate.

a. Lateral boundaries exist where two plates slide and grind past each other as they move in parallel or opposite directions.

b. Convergent boundaries exist where two plates collide and destroy lithosphere by compacting, or shortening, and melting. There are two major types of convergence:

   When two ocean boundaries or an ocean boundary and a continental boundary collide, an ocean plate edge sinks, and melting occurs. Plate boundaries of this type are associated with ocean trenches, coastal mountain ranges (e.g. Cascades), and island arc volcanoes. The melting forms magma, which rises, creating the volcanoes of the island arcs.

   When two plates that have continental areas at their convergent boundaries collide, the lithosphere crumples up and new young mountain ranges form. This is happening today where India is colliding with Asia, forming the Himalayan Mountains.

c. Divergent boundaries exist where two plates diverge or separate, as at mid-ocean ridges. Divergence results in the formation of new lithosphere and crust, because separation allows liquid rock, or magma, to rise from the mantle below, forming volcanoes and new rock.

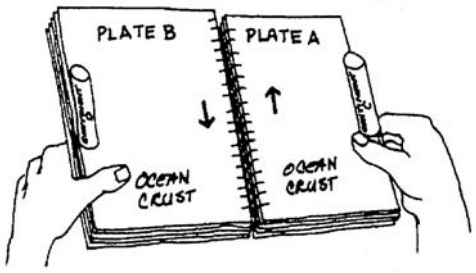
2. Tell the class that they are going to make some simple models of two major types of plate boundaries. If the class has never done hand motions to model the activity at plate boundaries, do Activity Three from the Grades 3-4 section of this unit first.

3. Ask students to get out their notebook paper and make two stacks of five sheets each. Then give them the following directions:

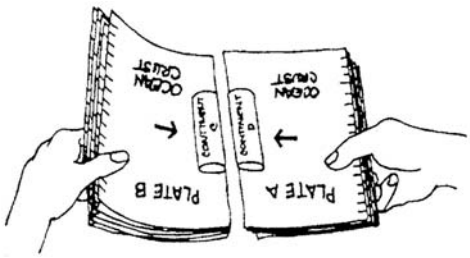
a. Using large letters, label the top sheet of one stack **Plate A** and the top sheet of the other **Plate B**. From now on, we will refer to the stacks of paper as "plates."

b. With scissors, cut .5" (1 cm) slashes at 1" (2 cm) intervals, fringing the long side of each plate. These slashes will represent the broken-up, crushed rock at the plate boundary.

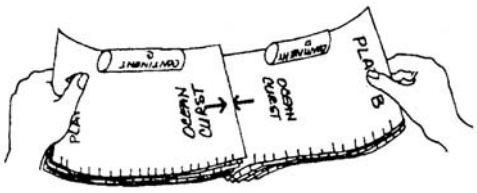
Teacher Take Note: To conserve paper use recycled paper or have students work in small groups.



Lateral boundary: Edge slide, but sometimes catch and jerk.



Convergent boundary with continents: Plate edge humps up, and may form mountains over time.



Convergent boundary with oceanic crust: One plate edge is forced under the other. This process may account for the formation of oceanic trenches.

c. Hold the plates together, one in each hand, in front of you. Push one plate forward and pull the other back towards your body.

   What did you feel? (sliding with frequent hitches as the slashed edges engage)

   What do you think this model represents? (A lateral plate boundary. The sliding motion represents fault creep, and the jerky motion represents the buildup and release of energy in an earthquake. The San Andreas lateral boundary in California exhibits this kind of motion. Plates slide, but locking of sections occasionally results in earthquakes.)

4. Tell students that next they will use their **Plates A** and **B** to model another type of plate boundary. Give these directions:

a. Label the top of each plate **Ocean Crust**.

b. Cut the sheet of colored construction paper in half lengthwise, and make a loop out of each section. Tape the loops closed, and press down on each one gently to flatten it.

c. Label one loop **Continent C** and the other **Continent D**, or make up names and write them on the loops. These loops will represent continents or continental crust.

d. Tape the middle of each loop to the short side of one of the plates with the closed side facing out.

e. Hold a plate-continent combination in each hand with the continent edges facing each other. Push the two plates together and observe what happens to the continents riding on the plates.

   What do you see? (The plates will hump up and the edges of the continents will rise.)

   What might this represent? (The demonstration represents the convergence of two plates, the shortening or folding of the crust and the formation of mountains.)

f. Turn the plates around so their plain short edges (without continents) face each other, then push those edges together.

   What happened? (One of the plates slid under the other.)

   What might this represent? (It represents two plates of oceanic crust converging. The depression which results represents an oceanic trench.)

5. Help students to summarize their observations, and answer any questions they may have.

Activity Three: The History of Geography

Materials for the teacher

- Transparency made from Master 18, Convection Currents and Plate Cross Section
- Transparency made from Master 19, Formation and Break-up of Pangaea
- Overhead projector
- Materials and directions from Unit II, Level 2, Activity Four
- World map or globe

Procedure

1. Ask students what they think might cause the Earth's plates to move. Accept various suggestions, then explain that the mechanism of plate movement is one of the major unsolved mysteries in Earth studies. The most widely accepted explanation is that convection currents in the Earth's mantle drive the plates. If students are not clear on the definition of *mantle*, review the definitions in Level 1.

2. Briefly describe convection currents, and project Master 18, Convection Currents and Plate Cross Section. Give several common examples of convection, such as hot air rising and cold air falling in the classroom, or warm water rising to the top and cool water sinking to the bottom in a lake or pool.

3. Discuss possible energy sources for convection and the movement of plates. (Many Earth scientists believe that heat energy is produced within the interior of the Earth, perhaps by the decay of radioactive materials like uranium and radium within the core and mantle.)

200,000,000 years ago

65,000,000 years ago

Today

50,000,000 years from now

Master 19, Formation and Breakup of Pangaea

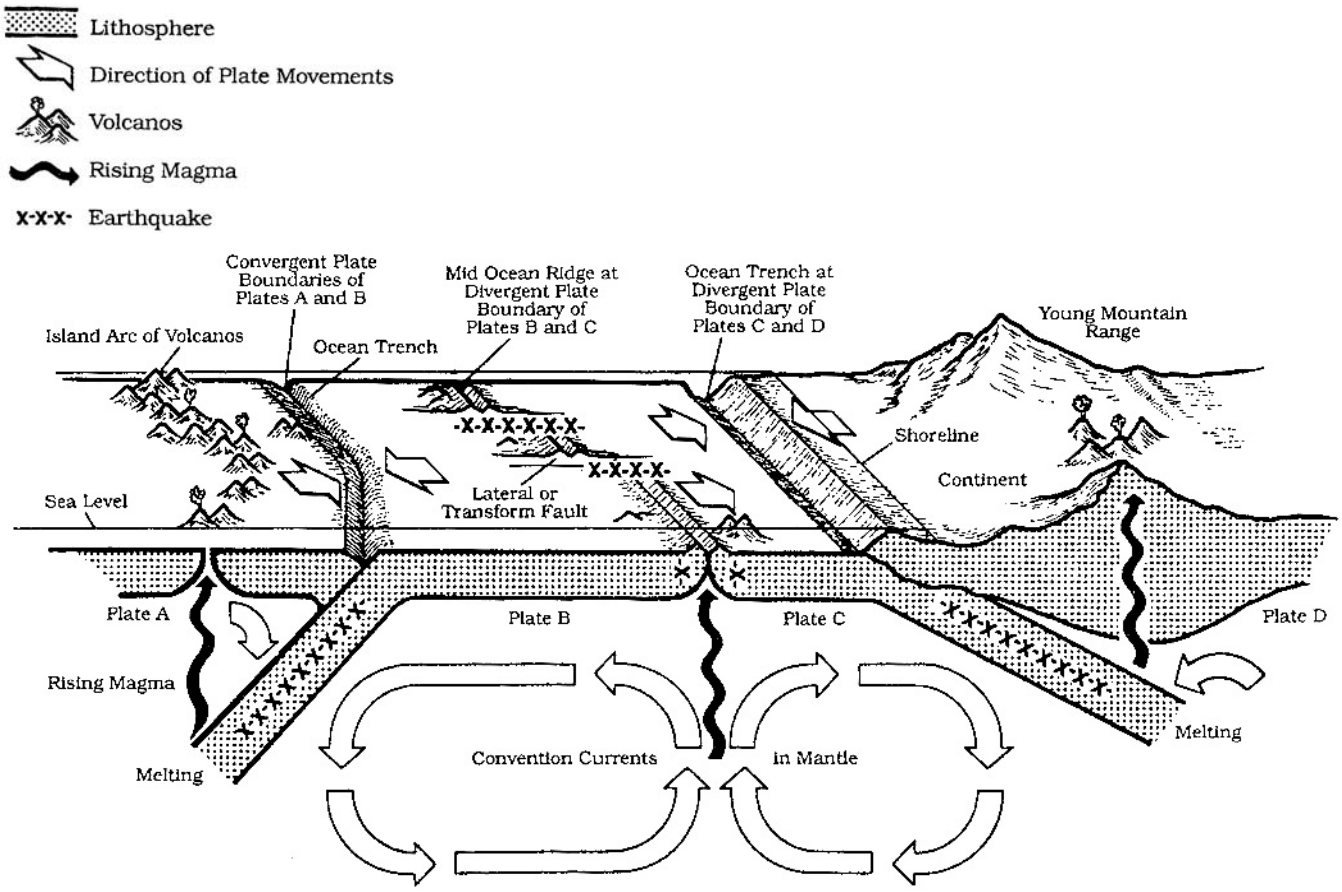
4. Refer to a globe, a world map, or a transparency of a world map, and ask how Africa and South America could fit together, almost like parts of a jigsaw puzzle. Students may see a similar fit among Europe, North America, and Greenland. Query class for a reason for this fit, and lead up to a brief discussion of Pangaea, the supercontinent of 200,000,000 years ago.

5. Using the transparency of the breakup of Pangaea (Master 19), very briefly show how we think the supercontinent changed to become the continents of today. Be sure to emphasize that the continents move only as parts of plates, not by themselves.

6. Indicate to the class that they are going to observe a model showing how convection currents could move the plates and the continents that ride on them. This model may explain the breakup of the supercontinent Pangaea over the last 200,000,000 years.

7. Do Activity Four, "Hot Stuff Rises and Cold Stuff Sinks," from Level 2 of this unit.

8. Again direct students' attention to the transparency of Master 18, Convection Currents and Plate Cross Section. Point out and briefly discuss what happens where convection currents rise and sink.



Activity Four: Flippin' through Pangaea

Materials for the student

- 1 copy of each Master 20a through 20d for each student
- Scissors
- Stapler (in classroom)

Procedure

1. Tell the students they are going to construct a flip book that illustrates the last 200,000,000 years on Earth. (You may want to show a finished book to emphasize careful cutting and to give the general idea.)

2. Direct students to very carefully cut masters 20a, 20b, 20c, and 20d apart on the straight lines. After cutting, they should stack the rectangles in sequential order. Numbered corners should be face up and in the upper left corner. The two blank ellipse panels should be on the bottom.

3. Align lower edges by tapping on a hard surface. Then align the left edges similarly. Hold the stack with both hands, having thumbs on top. Bend the stack back and forth several times until the edges on both sides are "slightly" offset. Hold the book with your right hand and staple it together (in far enough to include all the pages, about .5 cm.)

4. Ask students to describe the changes in the pictures from panel 1 to panel 22. (The large dark mass, "Pangaea," breaks apart, and the continents as we know them today are formed.) Ask students to make predictions about what will happen to the continents in the future. (There will be further movement of continents in the same direction.)

5. Direct students to draw their predictions on the last two blank ellipses. (Remind students that they should make their drawings sequential.)

6. Have students discuss their predictions and drawings.

Unit II. Why and Where Earthquakes Occur

Materials List

Grades K-2
hard-boiled egg
permanent marker
dental floss or butter knife
construction paper
toothpicks
modeling clay
paper
crayons
markers
scissors
paste or glue
overhead projector

Grades 3-4
globe
crayons
colored pencils
glass baking dish or aquarium
immersion heater
plastic bag with twist tie
tape
eyedroppers
red food coloring
blue food coloring
ice cubes
hard-boiled eggs
small kitchen knife
overhead projector
narrow permanent marker
broad permanent marker
paper circles from hole puncher

Grades 5-6
unlined paper
pencils
metric stick
watch with second hand
colored pencils or crayons
lined paper
colored construction paper
scissors
transparent tape
metric ruler
glass baking dish
plastic bag with twist tie
immersion heater
tape
red food coloring
blue food coloring
eyedroppers
paper hole punches
ice cubes
globe
overhead projector
transparency markers