Earthquakes 3–5

Earthquake Science

American Red Cross

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Plate Tectonics

Plate tectonics are integral to understanding earthquakes, their causes and their effects.

Key Terms and Concepts

continental drift	magma	plate tectonics
continental plates	oceanic plates	seafloor spreading
lava	Pangaea (pan-gee-ah)	Alfred Wegener

Purpose

To introduce the students to the supercontinent of Pangaea and the theory of plate tectonics

Objectives

The students will—

- Read *Facts About Pangaea* and create a mind map to define plate tectonics: theories, history and evidence
- Discuss a simple demonstration of convection currents, if they are unfamiliar with the concept.
- Use *Pangaea Puzzle* to illustrate how the plates of the supercontinent separated and moved to form our world.
- Use a Web animation to discuss possible future changes in the earth's land masses. (Linking Across the Curriculum)
- Work a puzzle on the Internet to see how the modern continents can be moved to form Pangaea. (Linking Across the Curriculum)
- Discuss information from *Facts About Pangaea* and *Inside the Earth* (from Lesson Plan 1) to answer questions about the earth's crust.
- Project what might happen when pieces of the earth's crust collide.
- Use *Chocolate Crust* to complete experiments that will prove or disprove their conjectures on mountain building.
- Discover and share information about mountain formation in America's national parks. (Linking Across the Curriculum)
- Solve a problem based on a geological scenario. (Linking Across the Curriculum)

Activities

"Puzzling Pangaea"

"Diving Plates"

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LESSON PLAN 2

Plate Tectonics

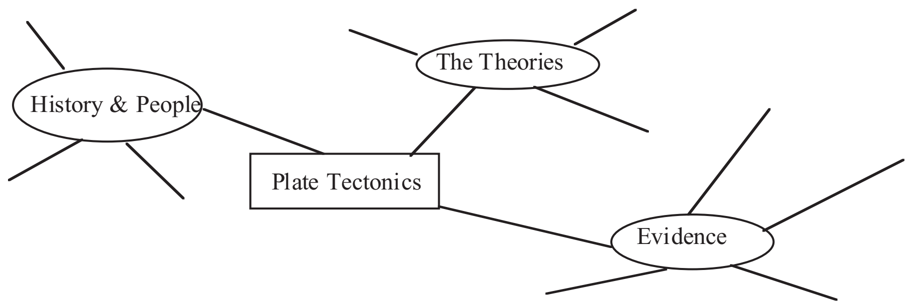
“Puzzling Pangaea”

SET UP 15 minutes **CONDUCT** 45 minutes

Science: Earth Science; Mathematics: Modeling; Social Studies: Geography

1. Have the students use a globe to locate the continents. If the continents were puzzle pieces, which continents would fit together easily? Does the map suggest that, some time in earth’s history, there could have been only one large continent? Explain. (Possible answers: South America and Africa look as though they could fit together; northeastern Asia and northwestern North America seem as if they’re almost touching.)

2. Distribute *Facts About Pangaea*. Provide time for the students to read the information. Draw a diagram, similar to the one below, on the chalkboard to set up a mind map for students.



Wrap-Up

Working together as a group, have the students place information from the activity sheet into a mind map, expanding each of the sections of the map with specific facts from the handout.

TEACHING NOTE If the students are unfamiliar with the concept of convection currents as described in the activity sheet, have them watch and discuss this very simple demonstration.

Set Up: Cut a piece of aluminum foil into a spiral. Using a needle, pull a piece of knotted thread through the center portion of the spiral. Light a bulb. Then, hold the aluminum foil spiral by the thread, so that it falls freely just a few inches above the lighted bulb.

Observation: The foil spiral begins twirling and continues as long as it’s close to the lighted bulb. The foil stops twirling when removed from the bulb or if the light is turned off.

Materials

- Globe
- *Facts About Pangaea*, 1 copy per student
- Chalkboard and chalk or chart paper and markers
- *Pangaea Puzzle*, 1 copy per student

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Explanation: The lighted bulb emits heat that warms the surrounding air. Warmer air is less dense, so it rises and causes the motion that turns the spiral. The air cools as it moves away from the heat source and falls back down, only to be heated again. This continual motion is called a convection current. (Molten rock, though much denser than air, is also fluid, and convection currents keep the outer layer of the earth's mantle moving slowly, dragging tectonic plates along with it.)

Distribute *Pangaea Puzzle*. Have the students cut the pieces of the puzzle apart to illustrate how the plates have moved to form the continents we know today. Discuss with the class whether or not the continents we know are still moving.

Linking Across the Curriculum

Science: Earth Science and Technology; Social Studies: Geography

In 1912, scientist and meteorologist Alfred Wegener theorized the huge landmass that was once Pangaea. Today, scientists have taken the theory from the past into the future, using computer modeling. Use the animation at *http://www.nytimes.com/packages/html/science/20070109_PALEO_GRAPHIC* to follow the movement of the earth's plates millions of years into the future, and then ask the students to describe the changes the earth could expect during that time.

Science: Earth Science and Technology; Social Studies: Geography

Cornell University has an excellent interactive map to show students how today's continents were once sections of one large landmass, Pangaea. Direct the students to the "Continental Puzzle" at *http://atlas.geo.cornell.edu/education/student/continental_puzzle.html* to see how well they can "puzzle Pangaea."

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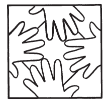

"Diving Plates"

SET UP 20 minutes **CONDUCT** 40 minutes

Science: Earth Science; Mathematics: Modeling

TEACHING NOTE For dense chocolate bars, use thick, chewy chocolate rolls or thick, solid chocolate bars. For soft chocolate bars, choose "spongey" candy bars, including those with marshmallow, mint cream or coconut centers. Avoid candy bars with peanuts, dense caramel or cookie centers.

For a non-food alternative, use a lead eraser in a block shape (the dense material) with a similar-size piece of Styrofoam (the less dense material).

1. Talk with the class about what they have learned concerning the earth's crust.

TEACHING NOTE If the students need reminders, or if you did not complete the previous activities, distribute *Facts About Pangaea* and *Inside the Earth* to guide student discussion.

- What are the two kinds of crust? (oceanic and continental.)
- What is the difference between these two kinds of crust? (Oceanic crust is considerably thinner and younger than continental crust.)
- What causes plates to diverge, or move in opposite directions? (Convection currents in the mantle cause the plates to continuously move and separate.)
- How does this affect the crust of the earth? (The crust shifts and separates. New magma rises from the mantle and erupts through the weakened crust along a spreading ridge, forming new oceanic crust that continues to spread away from the ridges as the new plates continue to separate. This is called seafloor spreading, and it is a central part of the theory of plate tectonics.)
- Where is crust the youngest and where is it the oldest? Explain. (Oceanic crust, especially at each of the ocean ridges, is youngest. Continental crust is usually crust that was first formed in the ocean and has traveled on its plate for a long time. Therefore, it is the oldest.)
- How might students explain why the oldest crust is usually the densest? (Possible answers include—Perhaps because it has had a chance to become layered with sediment. The pressure from these accumulating layers will force the crust material closer together, making it denser.)

Materials

- *Facts About Pangaea* (optional), 1 copy per student
- *Inside the Earth*, from Lesson 1: What's Inside? (optional), 1 copy per student

For each group of 2–3 students:

- *Chocolate Crust*
- 3 large, dense chocolate bars
- 3 large, soft chocolate bars
- 1 large sheet of waxed paper

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2. Invite the students to speculate about what they think happens when oceanic crust collides with denser, continental crust. What about the pressure of oceanic crust against oceanic crust? Or continental crust against continental crust? Write all hypotheses on the chalkboard or chart paper.

3. Divide the students into small groups of two to three scientists; distribute *Chocolate Crust* and the candy bars and waxed paper to each group. Have the student teams try each experiment to see if they can model answers to the questions above to prove or disprove their original hypotheses.

4. When the groups have completed their experiments, have them share their experiences and observations.

Answers to *Chocolate Crust*

Experiment 1

The denser bar (continental crust) rises above the lighter bar (oceanic crust); or conversely, the lighter bar (oceanic crust) plunges below the denser bar (continental crust). This illustrates what the plates do—the denser continental plate rises above the lighter oceanic plate when they push against each other.

Experiment 2

The two dense bars (continental crusts) will fold or push upward. That is, the ends will push into each other and up. The same thing happens when two continental plates press into each other. Folded mountains, such as the Rockies, Appalachians, Himalayas and Andes, are the result of two continental plates pushing into each other.

Experiment 3

The two less-dense bars will fold or push upward. The results on the ocean floor are folded mountains rising up above the earth's crust. The mountains of the ocean's depths are formed in this manner.

Wrap-Up

Challenge the students to transfer the ideas they developed using chocolate-bar models to actual events in the earth.

What happens to the oceanic crust as it is pushed beneath the heavier continental crust? (Possible answer: As it is pushed down, the pressure and heat increase and the crust melts and turns into magma, becoming part of the mantle.)

How are the earth's mountains, especially those at the edges of the plates, formed? (Possible answer: Colliding continental plates often push against each other, forcing upthrust.)

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Linking Across the Curriculum

Science: Earth Science and Technology; Language Arts: Research

The movement of plates or the eruption or movement of magma forms mountains. The U.S. Geological Survey (USGS) has a great deal of information about how mountains were formed across the United States: fold mountains, fault-block mountains, dome mountains and volcanic mountains. Have the students access Geology of the National Parks at *http://wrgis.wr.usgs.gov/parks/* to discover and share how plate tectonics affect the world around us.

Science: Earth Science; Language Arts: Research; Mathematics: Calculation and Estimation

Miners found copper in the Wrangell Mountains of south central Alaska. Actually, the copper was first deposited on the Pacific Plate when a volcanic island arc formed west of today's Baja Peninsula 300 million years ago. Challenge the students to use a map of the major plates on the earth's surface (USGS for a simple, static map of the plates, *http://geology.er.usgs.gov/eastern/plates.html*; or USGS and the University of California at Berkeley for a dynamic map of the plates, *http://baird.si.edu/minsci/tdpmap/viewer.htm*) to find the answers to the following questions.

- Discover the name of the plate on which the copper deposits were probably first laid. (The plate on which the deposits were first laid is the Pacific Plate. It formed approximately 380 million years ago, during the Upper Devonian Period of the Paleozoic Era.)
- Calculate the distance the copper deposits had to travel in order to end up in southern Alaska. (The formation first occurred somewhere south of the equator, west of what is now the Baja Peninsula. Before colliding with the southern Peninsula of Alaska, it had to travel about 3,000 miles [4,800 kilometers], give or take 500 miles [800 kilometers].)
- Determine the direction of movement of this plate. (The plate moved northward and slightly westward.)

Now, as a class, use the information to discuss—

- How did the copper that was first brought to the earth's surface south of California end up in deposits in south central Alaska? (The copper was one of the minerals deposited in the volcanic eruption that occurred west of today's Baja Peninsula 380 million years ago when the Pacific Plate slid northward along the North American Plate. When it collided with the southern peninsula of Alaska, huge earthquakes and volcanoes erupted, spewing hot water that sank back into the prevalent type of rocks of the terrane that were lying atop the moving plates. The terrane (this area of particular type of rocks), known as the Wrangellia Terrane, accreted to the Alaskan Peninsula and stayed there. The copper in the original layers of the terrane stayed with it.)

- Figure the average distance the deposits traveled each of the 300 million years. (The deposits moved an average of approximately 1 one hundred thousandth [.00001] of a mile per year, or about 1/5 of an inch [1 centimeter] per year—a little more slowly than your fingernails grow!)

For more information on the geology of Wrangell-St. Elias National Park and Preserve, go to *http://www.nps.gov/wrst/*.

Facts About Pangaea

Name ____

In 1912, a German scientist named Alfred Wegener had the idea that the continents once formed a single huge landmass, which he called Pangaea. This word means “all earth.” He suggested that Pangaea broke into pieces. We call these pieces **plates**. The theory Wegener suggested to explain the drifting plates is called the **theory of plate tectonics** and is sometimes referred to as **continental drift**.

By 1929, Alfred Wegener’s ideas were all but dismissed. But, Arthur Holmes elaborated on one of Wegener’s hypotheses: thermal convection and the earth’s mantle. Thermal convection states that, as a substance is heated, its density decreases and it rises. Once it cools, its density increases and it falls. This continuing process causes a current. Within the magma in the upper level of the mantle, this powerful current can cause plates to break and continents to move in opposite directions, floating on the convection currents.

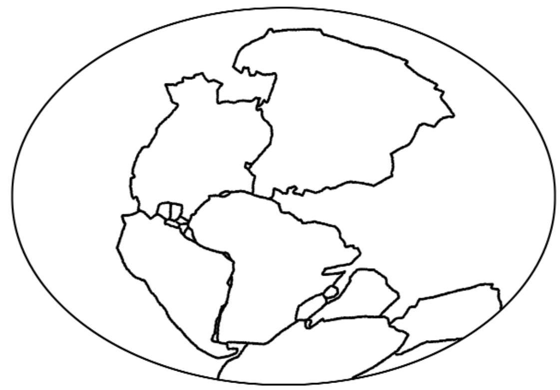
More than 30 years later, in the early 1960s, other scientists began looking into Holmes’s ideas to provide further illustration of Wegener’s theory of plate tectonics. Harry Hess and Robert Dietz believed that the Mid-Atlantic Ridge marked one place where Pangaea began to break apart. Their theories are that—

- Along the Mid-Atlantic Ridge, the ocean floor was ripped in two and continuously pulled apart lengthwise as the newly created, drifting plates floated apart.
- The rip formed a weak area in the crust.
- New magma rose and erupted through the weak crust along the spreading ridge and formed new oceanic crust.
- The new oceanic crust continuously spread away from the ridges as the new plates continued to separate.
- This process, called **seafloor spreading**, began many millions of years ago and continues to this day. Along the Mid-Atlantic Ridge, the erupting lava and drifting plates produced a huge basin that eventually filled with water to become the Atlantic Ocean.

Facts About Pangaea

Evidence for the Plate Tectonics Theory:

1. Here is the supercontinent of Pangaea, as it began to break up about 225 million years ago. Look at the image as if it were a puzzle that you could take apart to form today's continents. Use a world map to decide which piece you think represents which continent. This suggests that the continents were, in fact, once joined into one huge landmass, torn away from each other by the force of the convection currents in the mantle of the earth.



2. A second piece of evidence supporting the idea of drifting continents is the close match between fossils of *Glossopteris* (a genus of plants) and fossils of *Mesosaurus* (a genus of reptiles) found on the eastern tip of Africa and those found on the corresponding part of South America.

3. The geological structures of the rocks in southwest Africa and southeast Brazil are identical in their makeup and age. If Pangaea existed, these rocks would have been part of one landmass. Rock formations of similar makeup and age are found in Europe's Caledonian Mountains and in the Appalachian Mountains in the southeast United States.

4. The San Andreas Fault in California forms a section of the boundary between the North American Plate on the east and the Pacific Plate on the west. The western edge of California below San Francisco is actually on the Pacific Plate and has been moving northward with respect to the rest of the continent. Geologists have found sections of specific rock formations on opposite sides of the fault separated by hundreds of kilometers. Streams that cross the fault have been offset by earthquakes, and even fences and buildings are pulling apart, creating additional evidence of the Pacific Plate's movement.

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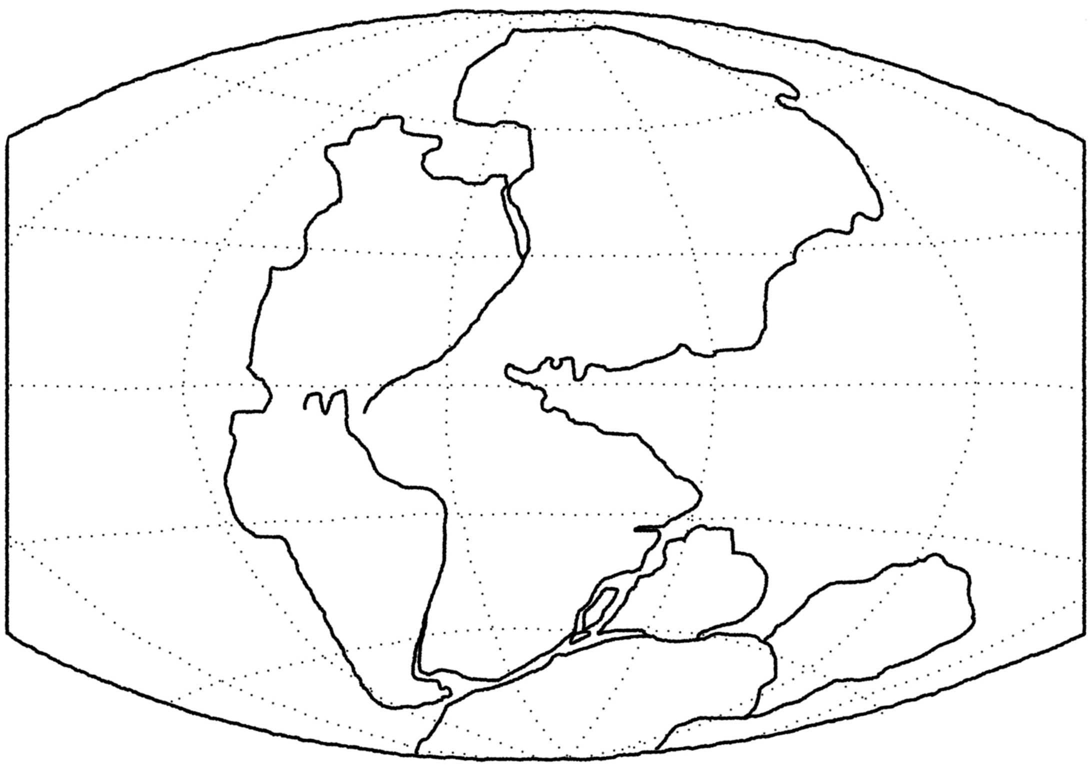
Pangaea Puzzle

Name ____

Scientists theorize that over 225 million years ago, the landmass of the earth looked like one supercontinent, Pangaea, meaning "all earth." Over the eons, the forces of plate tectonics broke up, moved and changed the single continent into the continents we know today.

Directions: Use a world map and your imagination to cut and separate Pangaea into today's world. Name the landmasses.



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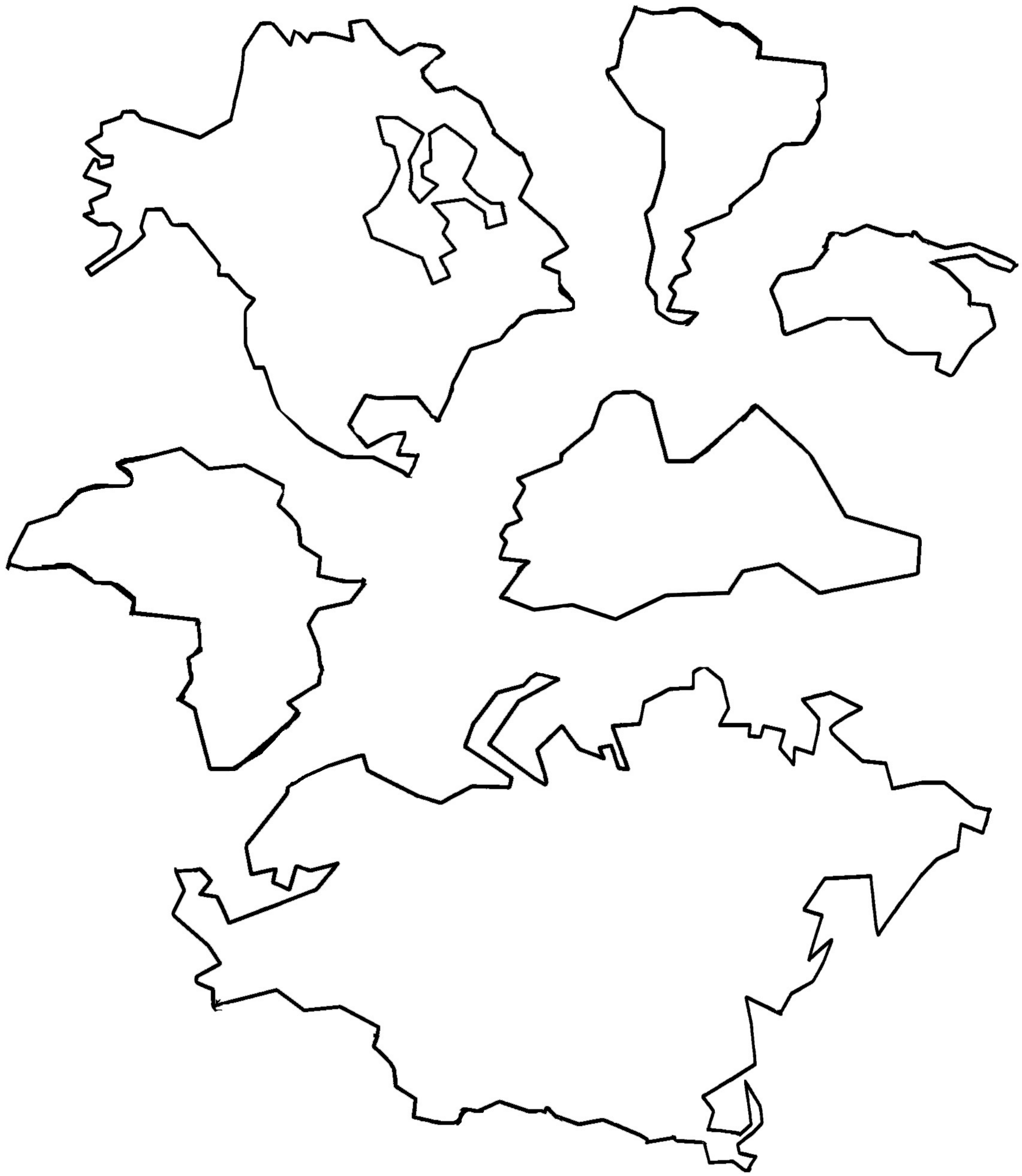
Pangaea Puzzle

Puzzle Pieces



Chocolate Crust

Name ____

Directions: The experiments below will help you formulate a theory about the effects of moving plates on the surface of the earth. Follow the steps to perform each of the three experiments to determine what might happen when pieces of the earth's crust collide.

You have been given—

3 dense chocolate bars
3 less-dense chocolate bars
waxed paper

The dense chocolate bars represent continental crust, and the less-dense chocolate bars represent oceanic crust. You will work on a surface of waxed paper.

After each experiment, discuss your observations within your team and then briefly summarize a theory to explain what happened on the lines provided. Appoint a member of your team to describe your observations and defend your explanatory theories to the class as a whole.

Experiment 1

1. Place one dense chocolate bar and one less-dense chocolate bar touching, end to end, on the waxed paper.
2. Then, push the bars together with a gentle, slow and steady pressure.
3. What happens to each of the bars at the point of contact? On contact? During contact? What is your theory to explain your observations?

Chocolate Crust

Experiment 2

1. Place one dense chocolate bar and a second dense chocolate bar touching, end to end, on the waxed paper.
2. Then, push the bars together with a gentle, slow and steady pressure.
3. What happens to each of the bars at the point of contact? On contact? During contact? What is your theory to explain your observations?

Experiment 3

1. Place one less-dense chocolate bar and a second less-dense chocolate bar touching, end to end, on the waxed paper.
2. Then, push the bars together with a gentle, slow and steady pressure.
3. What happens to each of the bars at the point of contact? On contact? During contact? What is your theory to explain your observations?