Plate Tectonics

D

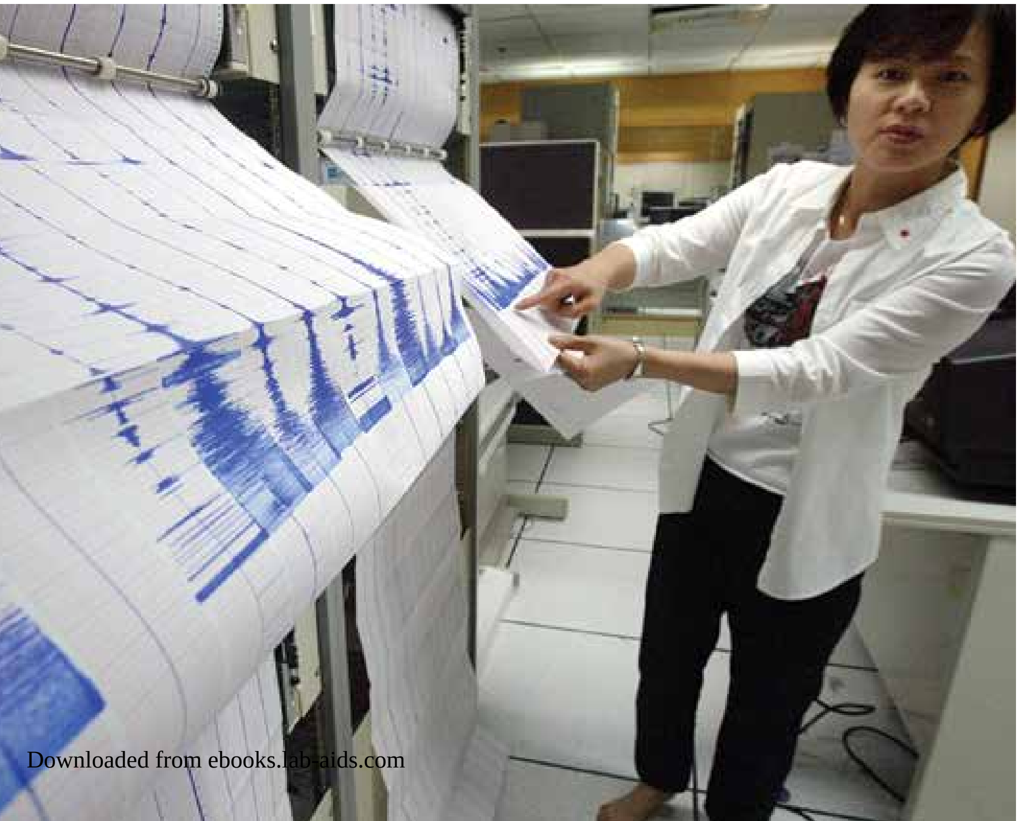


Plate Tectonics

Felix and his father were watching TV when they saw a news flash showing lava erupting from a volcano.

"Look at that!" said Felix. "It's a huge fire!"

The reporter said that no one had predicted that the volcano would erupt. Then a scientist explained that the volcano was part of a mountain range that had been formed by volcanic eruptions that occurred over thousands of years.

Felix and his family lived near the base of Mount Adams. It was the biggest mountain around. He asked his father, "Is Mount Adams a volcano? Could it erupt like that?"

"I'm not sure," answered his father. "We have a lot of mountains around here, but I've never heard of any of them erupting."

"Yeah, but Mount St. Helens in Washington erupted when Aunt Pilar lived nearby," thought Felix. "She told us they could see the ash from miles away. Maybe it could happen here."

• • •

What happens when a volcano erupts? Is a volcanic eruption likely to occur where you live?

In this unit, you will investigate volcanoes and earthquakes. You will find out how mountains are formed. You will learn about changes to the earth's surface that take place over very long periods of time.

36 Storing Nuclear Waste

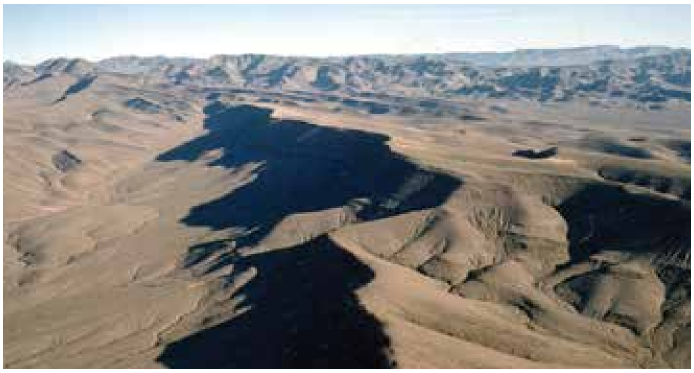
Each year the United States produces more than 60,000 tons of nuclear waste. Currently most of that waste is stored at the sites, such as nuclear power plants, where it is produced. The danger in storing nuclear waste is the possibility of it being released into the air or nearby bodies of water if the waste containers were to leak. People who inhale or ingest radioactive material are at increased risk of developing radiation-related illnesses. The level of risk depends on the dose and length of exposure.

For more than 50 years, scientists have been considering better ways to store nuclear waste. They have proposed sending it into space, placing it in the ocean floor, and burying it on a remote island. But all of those options pose problems—both known and unknown. Most experts now think that the safest solution is to store the waste in special containers placed in deep underground rooms.

In the early 1980s, the U.S. government reviewed several possible underground storage sites. In 1987, they chose Yucca (YUK-uh) Mountain in Nevada, and the Department of Energy prepared to build the storage site. However, in 2011, they withdrew their application for the site. The example of Yucca Mountain highlights the scientific and social issues involved in choosing a site for storing nuclear waste.

In January 2012, the Commission on America's Nuclear Future, appointed by President Barack Obama, released a report on the management of nuclear waste. It recommended that one or more deep disposal sites should be developed.

Yucca Mountain is 6.5 to10 km wide (4 to 6 miles) and 40 km long (25 mi). At its highest point, it is 457 m (1,500 ft) high. The entire Yucca Mountain area is about 384 km^2 (260 mi^2).



CHALLENGE

What are the advantages and disadvantages of storing nuclear waste in Yucca Mountain?

MATERIALS

For each student

1 **Student Sheet 36.1, "Analyzing Evidence: Yucca Mountain"**

1 **Student Sheet 36.2, "Discussion Web: Yucca Mountain"**

PROCEDURE

1. With your group, read the background information about nuclear waste on the following pages. Have each person read one section aloud.

2. a. With your group, read aloud each statement on Student Sheet 36.1, "Analyzing Evidence: Yucca Mountain."

   b. Discuss each statement with your group.

   c. Record on Student Sheet 36.1, "Analyzing Evidence: Yucca Mountain," whether you believe the statement is based on scientific reasons or on social or political concerns.

   d. Record whether the statement provides an argument for (+) or against (–) Yucca Mountain as a place for storing nuclear waste.

   When discussing your ideas, remember to listen to and consider the ideas of other members of your group. If you disagree, explain why.

3. Use Student Sheet 36.2, "Discussion Web: Yucca Mountain," to sort the evidence. Note: Do not copy the statements directly.

   a. In the "Yes" column, explain how a particular piece of evidence supports storing nuclear waste at Yucca Mountain.

   b. In the "No" column, explain how a particular piece of evidence does not support storing nuclear waste at Yucca Mountain.

Background Information about Nuclear Waste

WHAT IS NUCLEAR WASTE?

NUCLEAR WASTE IS the leftover radioactive material produced by nuclear power plants, nuclear research, nuclear medical treatments, and other nuclear technology. Radioactive materials release a type of energy that can't be seen, felt, or heard, but can damage living cells and cause diseases, such as cancer. Depending on the technology they are used for, such materials have high to low levels of radioactivity. Being exposed to highly radioactive materials for a short time or being exposed to low levels of radioactivity over long periods of time increases the risk of cancer and early death.

A nuclear power plant

Most nuclear waste comes from nuclear power plants and government defense projects. Most of it is in the form of highly radioactive solids made of metal, ceramic, or glass. Some of these solids will remain radioactive for a few years, while others are likely to be dangerous for at least 250,000 years.

HOW ARE PEOPLE PROTECTED FROM NUCLEAR WASTE?

There is no danger that nuclear waste will explode, but it does release radiation. It is usually stored in ways that protect people from its harmful effects and prevent it from leaking into the environment. A lot of nuclear waste is stored in containers made of lead, steel, and concrete, which shield people from the radiation. These containers are built to resist impact, high temperatures, and corrosive chemicals. It is possible that eventually water would damage these containers and cause them to leak. That is one reason why it is best to store nuclear waste containers in relatively dry areas. The most likely danger from nuclear waste is if it is accidentally released into the air or water, where it can spread throughout the environment and might be ingested or inhaled.

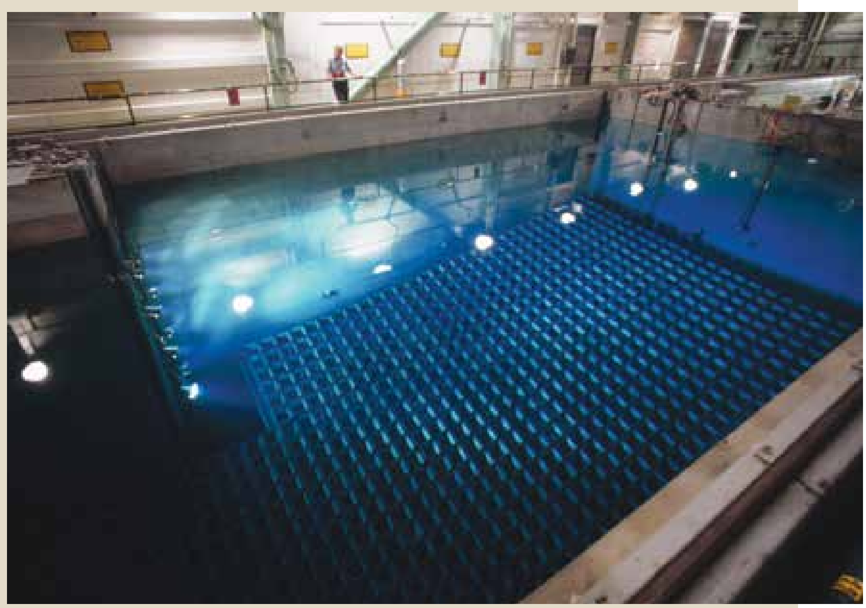
HOW MUCH WASTE COMES FROM NUCLEAR REACTORS?

About 20% of the electricity in the United States comes from its 104 nuclear power plants. Over the years, these power plants, which generate much of our electricity, have produced more than 65,000 metric tons of nuclear waste. If these power plants continue to operate to the end of their current licenses and no new nuclear power plants are built, the amount of nuclear waste to store will approach 150,000 metric tons by the year 2050. If more plants were built to help meet our electricity demands, this number would increase to as much as 200,000 metric tons.

WHERE IS NUCLEAR WASTE STORED NOW?

Nuclear waste is currently stored at 125 temporary sites in 39 states. These sites are located in cities, suburbs, and rural areas. More than half the U.S. population now lives within 121 km (75 mi) of stored nuclear waste. Some of the sites are in areas where earthquakes or hurricanes occur, some are near surface or groundwater sources that provide drinking water to communities, and some are near major cities.

When nuclear fuel is first removed from reactors, it is placed in deep pools of water. The water helps to cool the fuel and protect workers from radiation. About 50,000 metric tons of nuclear waste are currently stored in pools. At some power plants the cooled nuclear waste is transferred to dry storage. About 15,000 metric tons of nuclear waste are currently stored in dry containers above ground. Nuclear experts believe that it is possible to create places hundreds of meters below the earth's surface where up to 70,000 tons of nuclear waste can be safely stored for at least 10,000 years.



Nuclear power plants use radioactive fuel rods. When these rods can no longer be used to produce energy, they are first placed in pools of water to cool before being shipped to nuclear waste disposal sites.

ANALYSIS

1. What other information would you like to have before you make a decision about a proposed long-term nuclear waste site, such as Yucca Mountain? Be sure to explain how this information would be helpful.

2. Do you think that one or two sites deep in the ground would be better than the current situation? Explain by

   a. stating your decision.

   b. supporting your decision with as many pieces of evidence as you can.

   c. discussing the trade-offs of your decision.

3. What role do you think each of the following should play in the selection of a long-term nuclear waste site?

   a. Scientific evidence

   b. Social or political concerns

4. **Reflection:** Would you agree to have nuclear waste stored near where you live? Why or why not?

EXTENSION

Visit the *Issues and Earth Science* page of the SEPUP website for links to more information about the long-term storage of nuclear waste. How do these sites help answer your questions?

37 Volcanic Landforms

MODELING

Most people think of volcanoes as destructive. The high temperature of volcanic lava can burn almost everything in its path. Volcanoes also release large amounts of gas and ash that can cause other types of damage. But volcanoes can also be constructive because they form rocks that can eventually result in new landforms.

Millions of years ago, explosive volcanoes erupted in the Yucca Mountain area. These eruptions released ash and hot liquid rock called magma. As this material cooled, it formed the layers of rock that make up Yucca Mountain. Not all volcanic eruptions are the same. Some of the rock found in the Yucca Mountain area is from later volcanic eruptions. These eruptions were smaller and much less explosive. The force of an eruption is affected by the amount of gas in the magma.

CHALLENGE

How do volcanic eruptions vary?

Some volcanic eruptions are explosive, while others release magma more slowly.

MATERIALS

For the class

1 sample of basalt rock
1 sample of pumice rock

For each group of four students

1 vial of baking soda
1 60-mL bottle of less gassy "magma" (red)
1 60-mL bottle of more gassy "magma" (colorless)
1 cup of water
1 plastic volcano model with base
1 clear, colorless plastic tube
1 rubber stopper
1 white plastic scoop
1 30-mL graduated cup
paper towels and/or a sponge

For each student

1 pair of safety goggles

SAFETY

Both types of "magma" contain dilute acid. Wear safety goggles and avoid direct contact with skin and eyes. Wash your hands after completing the activity.

PROCEDURE

Part A: Eruption of Less Gassy Magma

1. In your science notebook, make a table like the one below.

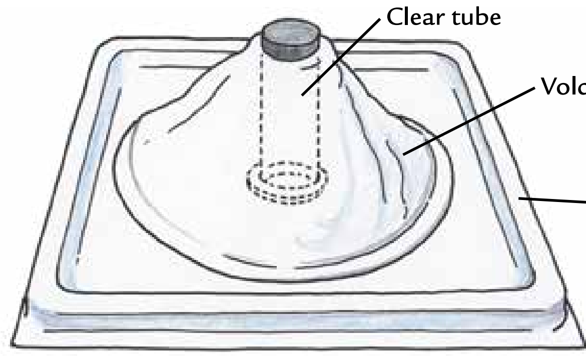
Observing Eruptions

Type of Eruption	Trial 1	Trial 2
Less gassy "magma"		
More gassy "magma"		

2. Work with your group to set up your volcano model as shown below by following these steps:

   a. Gently push the clear tube into the mouth of the white volcano cone.

   b. Set the base of the clear tube into the hole of the square plastic tray.



3. Place 1 scoopful of baking soda into the bottom of the volcano tube.
4. Use the graduated cup to measure and pour 5-mL of less gassy "magma" into the tube.
5. Without disturbing the model, observe it carefully for two minutes.
6. Record your observations in your science notebook.
7. Rinse your volcano model.
8. Then repeat Steps 3–7. Be sure to switch roles among your group members.

Part B: Eruption of More Gassy Magma

9. Use the graduated cup to measure and pour 2.5 mL of more gassy "magma" into the volcano tube.
10. Dip your finger into water and use it to moisten the bottom of the rubber stopper.
11. Dip the bottom of the stopper into the baking soda so that a thin layer of baking soda sticks to it.
12. Gently cap the volcano tube with the stopper. Try not to spill any baking soda and insert the stopper snugly into the tube.

13. Quickly turn the entire volcano model upside-down and then put it back on the table right-side up.

    Hint: Balance the volcano model on the palm of one hand. Use the other hand to hold the stopper and tube in place. Turn the model upside-down and right-side up, as shown below. Quickly set the model on the table right-side up.

14. Without disturbing the model, observe it carefully for two minutes.
15. Describe what you observe in your science notebook.
16. Rinse your volcano model.
17. Repeat Steps 9–16. Be sure to switch roles among your group members.
18. Your teacher will pass around two types of rock formed from cooling magma: basalt and pumice (PUM-is). Compare the two rocks. In your science notebook, record which rock is more likely to have been formed from: (a) less gassy magma and (b) more gassy magma. Explain your reasoning.

ANALYSIS

1. **a.** Describe the similarities and differences between the eruptions of less gassy and more gassy magma.

   b. Which type of magma produced a more explosive eruption?

2. Over time, there have been both very explosive and less explosive eruptions in the Yucca Mountain area. Which type(s) of volcanic rock might you find there? Explain your reasoning.

3. Imagine a volcano erupting many times over a period of years. Which of the following landforms is most likely a result of volcanic eruptions: a valley, a mountain, or a canyon? Explain.

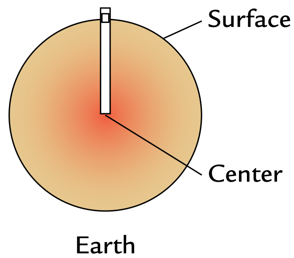
4. What were the strengths and weaknesses of the volcano model? **Hint:** Think about ways in which the model did or did not represent real volcanic eruptions.

38 Beneath the Earth's Surface

READING

When volcanoes erupt, magma is released. Where does this magma come from? To answer this question, it helps to know more about the earth.

Imagine taking a glass elevator to the center of the earth. What would you see?



CHALLENGE **What is beneath the earth's surface?**

MATERIALS

For each pair of students

1 calculator
colored pencils (optional)

For each student

1 Student Sheet 38.1, "Talking Drawing 1: Beneath the Earth's Surface"
1 Student Sheet 38.2, "Talking Drawing 2: Beneath the Earth's Surface"
1 metric ruler
1 compass (optional)

READING

Use Student Sheet 38.1, "Talking Drawing 1: Beneath the Earth's Surface," to help prepare you for the following reading.

On the Earth's Surface

A **volcano** is an opening in the earth from which magma and gas erupt. Gases within the magma build up enough pressure to force it upwards and eventually through gaps in the earth's surface, causing an eruption. Once magma has erupted onto the earth's surface, it is called **lava** (LAH-vuh). As it cools, the lava forms volcanic rock. Over time, volcanic rock and ash can result in a hill or mountain around the opening. This resulting landform is also called a volcano.

Volcanic eruptions are not all alike. Some eruptions are gentle, with lava slowly seeping from a vent. Other eruptions are violent, with lava, ash, and other materials being hurled hundreds of kilometers into the air. Differences in volcanic eruptions result in different volcanic mountain shapes, such as shield volcanoes, cinder cones, and composite volcanoes. You can see examples of each of these shapes in the photographs on the next page.

Scientists who study volcanoes are known as volcanologists (vul-ka-NOL-o-jists). These volcanologists are measuring the temperature of an active volcano.

There is a lot of evidence of volcanic activity on earth. Many mountains have been formed from volcanoes that are now extinct or dormant. Yucca Mountain was formed from volcanic material exploding from a composite volcano that is now extinct. The Cascade Mountain Range that extends from British Columbia through Washington, Oregon, and Northern California, was mostly formed by volcanoes. Alaska's Aleutian Islands and all of Hawaii are volcanic formations.

COMPARING VOLCANIC MOUNTAINS

a. ***Shield volcanoes,*** *such as Oregon's Mount Bachelor, shown here, usually form large, broad volcanoes. They release relatively fast-moving, less gassy lava, and tend to have less explosive eruptions than other types of volcanoes. People can often walk fairly close to these erupting volcanoes.*

b. The smallest and most common volcanoes are called ***cinder cones.*** *They are formed from explosive eruptions that shoot small pieces of magma and ash into the air. The magma then cools and hardens as it falls back to the earth, forming a cinder cone. In many cases, cinder cones form on the sides of a larger volcano. This photo shows a cinder cone on Mount Etna, in Italy.*

c. ***Composite volcanoes*** *have explosive eruptions as a result of more gassy magma. They are formed from layers of lava and ash. Composite volcanoes are also known as* ***stratovolcanoes.*** *This photo shows Mount St. Helens, Washington, a composite volcano, before its 1980 eruption.*

Inside the Earth

Early evidence about the inside of the earth came from volcanic eruptions. In the last hundred years, scientists have been learning more about the earth using technology and new methods for gathering evidence. For example, scientists have learned a lot from studying earthquakes. Earthquake waves move through different materials in different ways and at different speeds. In general, these waves move faster through more dense solids than they do through less dense solids. The waves move slowest through liquids. Scientists, such as the one shown below, measure the waves from a single earthquake at different places on the earth's surface. By analyzing and comparing the data from many earthquakes, they have been able to determine the state—solid, liquid, or gas—of the material inside the earth.

This geophysicist is using a GPS device to measure how much the land shifted after an earthquake.

Scientists now know that the rocks on the earth's surface are only a tiny fraction of what makes up the planet. Think of the earth as an egg. The thickness of the eggshell would represent the thickness of all the rocks at the surface. Beneath an eggshell there is egg white and yolk. What is beneath the rocks at the surface of the earth? Research indicates that the earth has three layers: a **crust**, a **mantle**, and a **core.** The core is made up of both a solid and a liquid layer, which are usually described separately as the **outer core** and the **inner core.** Information about each of these layers is summarized in the table on the next page.

Layers of the Earth				
	Approximate depth below surface (km)	**State**	**Material**	**Temperature (°C)**
Crust	0–40 (average)	solid	many kinds of rocks	0–700
Mantle	40–2,800	upper part is solid, lower part is liquid	iron, magnesium, and silicon compounds	700–2800
Outer core	2,800–5,200	liquid	iron and nickel	2,800–5,200
Inner core	5,200–6,400	solid	iron and nickel	over 6,000

The magma that erupts from volcanoes often comes from the mantle. Magma rising from the mantle can collect in underground chambers in the earth's crust, building up pressure before exploding toward the surface. The mantle is almost 3,000 km thick, which is about the same as the distance from New York City to Denver, Colorado. The land from New York to Colorado is not always the same, and neither are all the parts of the mantle. The uppermost part of the mantle is more solid than the lower part. Because the upper mantle and the crust are both solid, geologists have a name for the combination of these two layers: **lithosphere** (LITH-o-sfeer). *Litho* means "stone" in Greek, and the lithosphere refers to the first 100 km below the earth's surface.

ANALYSIS

1. Which layer(s) of the earth is (or are):

  a. the hottest?

  b. at the earth's center?

  c. completely solid?

2. Copy the five words shown below.

outer core upper mantle
lithosphere solid
crust

  a. Look for a relationship among the words. Cross out the word or phrase that does not belong.

  b. Circle the word or phrase that includes all the other words.

  c. Explain how the word or phrase you circled is related to the other words in the list.

Your teacher will give you Student Sheet 38.2, "Talking Drawing 2: Beneath the Earth's Surface." Use it and the information from the Reading to answer Questions 3 and 4.

3. Answer Parts a–h to create a scaled drawing of the earth's layers on Student Sheet 38.2. If you have time, you may want to color in the different layers.

a. How far is it to the center of the earth in kilometers (km)? Record this distance on Student Sheet 38.2.

b. Use a ruler to measure and record the distance from earth's surface to its center in centimeters (cm).

c. How many kilometers will a single centimeter represent? This is called a **scale.** Calculate and record your scale. **Hint**: You will need to divide the distance to the center of the earth in kilometers (km) by the scale.

d. Record the lowest depth of each earth layer in kilometers.

e Use your scale and a calculator to determine the scaled depth of each earth layer in centimeters.

f. Use a ruler to measure the depth of each layer, starting from the earth's surface. Draw a circle at each depth. **Hint:** After drawing the other layers, sketch the approximate location of the crust.

g. Label each layer with its name, state, and temperature.

h. Label the lithosphere. Be sure to record its actual depth in km.

4. At Yucca Mountain, nuclear waste will be stored at a depth of about 0.3 km (300 meters, or 1,000 feet).

a. In which layer of the earth will the waste be stored?

b. Place an "X" on that layer of your drawing on Student Sheet 38.2.

5. Compare your drawing on Student Sheet 38.1, "Talking Drawing 1: Beneath the Earth's Surface," with your drawing on Student Sheet 38.2. Describe the earth's interior and explain how your understanding of it has changed.

39 Earth Time

INVESTIGATION

The earth is over 4 billion years old. But modern humans have been around for only hundreds of thousands of years, or 0.01% of earth's history. That's why paleontologists use fossil evidence, as well as the radioactive decay in rocks, to figure out when things happened. **Paleontologists** (pay-lee-un-TALL-oh-jists) are scientists who use evidence from rocks and fossils to understand when events occurred in the history of life.

Volcanoes are found in 18 states in the United States. Since 1900, volcanoes have erupted in Alaska, California, Hawaii, Oregon, and Washington. Volcanoes in other states have not erupted for thousands, hundreds of thousands, or even millions of years. All of these time periods are very long compared to the average human lifespan. Paleontologists usually refer to time periods of thousands, millions, and billions of years as **geological time**.

CHALLENGE

When did particular events in earth's history occur?

Argentinian paleontologist Rodolfo Coria prepares the fossilized vertebrae of a dinosaur.

MATERIALS

For each group of four students

1 **set of 10 "Events on Earth" cards**

1 **Student Sheet 39.2, "Paleontology Student's Notes"**

For each student

1 **Student Sheet 39.1, "Ordering Events"**

PROCEDURE

1. Imagine that your friend is studying to be a paleontologist. She asks you to help her list some events in the history of the earth in order. She's interested in organizing her ideas into the four time periods shown on Student Sheet 39.1, "Ordering Events."

2. With your group, carefully read the information on the front of each "Event on Earth" card.

3. With your group, place each event in order, from oldest to most recent. **Hint:** If you need help, read the clue on the back of the card. Some clues will help you put the events in order, while other clues will help you identify the time period in which an event occurred.

   Remember to listen to and consider the explanations and ideas of other members of your group. If you disagree with the others, explain why you disagree.

4. Discuss with your group during which time period you think each event occurred.
5. On Student Sheet 39.1, "Ordering Events," record the order of events that you have decided upon with your group. Be sure to place each event in the time period in which you think it occurred.
6. Your friend suddenly remembers that she wrote down the order of these events in her science notebook. Ask your teacher for a copy of Student Sheet 39.2, "Paleontology Student's Notes," for your group.
7. Use the information on Student Sheet 39.2 to rearrange the cards in the order scientists have determined from geologic evidence.
8. Record this revised order on Student Sheet 39.1.

ANALYSIS

1. How did your group's original order of events differ from that of paleontologists? Explain.
2. Would units of time such as minutes and hours be useful in measuring events in earth's history? Why or why not?
3. Some nuclear waste may be radioactive for 250,000 years. Would you consider this to be a long or short period in geological time? Explain your reasoning.
4. Your younger brother tells you about a television show he watched where humans ride dinosaurs instead of cars. He says he wishes he could go back to the time when people lived with dinosaurs. Based on what you learned in this activity, what do you tell him?
5. **Reflection:** How did placing these events in order yourself help you to understand the earth's history? **Hint:** Think about how your understanding of events in geological time has changed.

40 The Continent Puzzle

Volcanoes occur all over the world. How likely is it that volcanic eruptions will occur at Yucca Mountain? To answer this question, it helps to study the past. You will find out more about the history of the earth in the next few activities.

In the early 1900s, Captain Robert Scott, who was from England, explored the continent of Antarctica. In his journal, he described finding plant fossils. These fossils were later identified as *Glossopteris* (gloss-OP-ter-iss), an extinct fern-like plant that grew on earth about 250 million years ago. *Glossopteris* grew in warm, wet areas, and could not have survived in an extremely cold place like Antarctica. How did the fossils of this plant end up in Antarctica?

CHALLENGE

What can rearranging the continents tell you about earth's history?

Captain Robert Scott's campsite in Antarctica.

MATERIALS

For each group of four students

- **1 set of 7 "World Puzzle" pieces**
- **1 Student Sheet 40.1, "Earth's Surface Through Geological Time"**

For each student

- **1 completed Student Sheet 39.1, "Ordering Events"**

PROCEDURE

Part A: The World Puzzle

1. With your group, carefully examine the location of the world's continents on the map on the next page.
2. Record the names of the seven continents in your science notebook.
3. Compare each World Puzzle piece to the continents on the map. Put a star next to each continent in your list that is represented by a puzzle piece. Then record the name(s) of any additional pieces.
4. Work with your group to arrange your puzzle pieces in locations similar to the ones shown on the world map.
5. Look at the symbols on some of the pieces. The symbols represent types of fossils or rocks found in several locations. The key to these symbols is shown below.

Key to Symbols on World Puzzle	
	Glossopteris, an extinct fern-like plant that could grow to 3.7 meters (12 feet) in height
	Mesosaurus (MESS-oh-saw-rus), an extinct freshwater reptile about 0.5 meters (2 feet) in length
	Cynognathus (sy-nog-NAY-thus), an extinct land reptile about the size of a wolf
	Lystrosaurus (liss-tro-SAW-rus), an extinct land reptile about 1 meter (3 feet) long
	Mountain ranges that have similar rock layers

CONTINENTS OF THE WORLD

The country of India can be seen on the Asian continent, in orange.

6. Work with your group to try to place all of the puzzle pieces into a single shape. Work together to decide where each piece belongs.

   Remember to listen to and consider the explanations and ideas of the other members of your group. If you disagree with other members of your group, explain why you disagree.

7. In your science notebook, sketch an outline of the final shape of your completed puzzle. Then, draw and label the individual puzzle pieces within your outline.

8. Move the pieces back into positions similar to the location of the continents today. Then slowly move the pieces back together into the single shape.

9. Discuss with your group what this puzzle might tell you about the history of the earth.

Part B: The History of Earth's Surface

10. Ask your teacher for a copy of Student Sheet 40.1, "Earth's Surface Through Geological Time," for your group.

11. Discuss with your group what you think has happened to the land on the surface of the earth during geological time.

12. Compare the outline that you sketched in Step 7 with Student Sheet 40.1. Identify when in earth's history the continents were arranged in a similar way. Record this time period, and the name of the land at this time, next to your sketch.

ANALYSIS

1. Describe what has happened to the land on the surface of the earth over the past 425 million years.

2. There are seven continents and there were seven puzzle pieces. But not every puzzle piece represented a continent. Why do you think this is? Hint: Think about how you used the pieces to model changes on the earth's surface.

3. What types of evidence did the puzzle provide about change on the earth's surface?

4. a. Look at the information in the table below, "Approximate Time Period of Some Extinct Organisms." On Student Sheet 39.1, "Ordering Events," record when each of these organisms lived.

   b. Pangea began to break apart about 200–225 million years ago. Record this event on Student Sheet 39.1.

   c. Which of the extinct organisms listed in the table below lived on Pangea before it broke apart?

Approximate Time Period of Some Extinct Organisms

Extinct Organism	Lived
Glossopteris (plant)	206–250 million years ago
Mesosaurus (reptile)	248–280 million years ago
Cynognathus (reptile)	230–245 million years ago
Lystrosaurus (reptile)	206–248 million years ago

EXTENSION

Go to the *Issues and Earth Science* page of the SEPUP website to link to animations showing the movement of continents over the last several million years. What do you notice?

41 Continental Drift

In 1915, a German scientist named Alfred Wegener (1880–1930) put together several kinds of evidence—including the location of fossils and rock layers on different continents—to come up with a new idea about the history of the continents. His idea was that the continents were once joined together to form a single large continent called Pangea. Over geological time, Pangea split apart and parts of it moved away to form today's continents. Today, this idea is called **continental** (kon-ti-NEN-tul) **drift.** "Drift" refers to the idea that the continents slowly moved away from each other, or *drifted* apart. In this activity, you will examine more evidence for this movement of continents.

CHALLENGE **What is the evidence that the continents have moved?**

Fossilized Glossopteris *leaves*

MATERIALS

For each student

1 **Student Sheet 41.1, "Analyzing Evidence: Continental Drift"**

PROCEDURE

1. Carefully read Student Sheet 41.1, "Analyzing Evidence: Continental Drift."
2. Discuss with your group what is evidence and what is not evidence.

   Remember to listen to and consider the ideas of the other members of your group. If you disagree with others, explain why you disagree.
3. On Student Sheet 41.1, look at each statement carefully and then mark whether you think it is or is not evidence. Check "yes" if you think it is evidence, and "no" if you think it is not evidence.
4. Cross out each statement that you have decided was not evidence. You will no longer consider these statements.
5. On Student Sheet 41.1, mark whether you think each piece of evidence does or does not support the idea that continents have moved. Check "yes" if you think it supports it, and "no" if you think it does not.
6. With your group, discuss:
   - **a.** whether you identified a statement as evidence or not.
   - **b.** how each statement you checked as evidence either supports or contradicts the idea of continental movement.

ANALYSIS

1. On Student Sheet 41.1, you identified statements that provide evidence in support of continental movement. Explain *how* each of these statements supports the idea that continents have moved.
2. Look again at Student Sheet 41.1. Have people other than Wegener contributed to the evidence in support of continental movement? Explain.
3. Imagine that you have been asked to write an encyclopedia entry about the movement of the earth's continents. Write a paragraph about continental movement, describing the history of this idea and citing as many pieces of evidence as you can.

42 The Theory of Plate Tectonics

VIEW AND REFLECT

In Activity 40, "The Continent Puzzle," you investigated the movement of continents. Today, geologists know that it's not just the continents that move—it is the entire surface of the earth! The earth's surface is broken into large sections called **plates.** These plates not only include the surface of the earth, but also extend down into the solid part of the upper mantle. This is one reason that geologists use the term "lithosphere." The movement of these lithospheric plates is called **plate tectonics** (tek-TAWN-iks).

CHALLENGE

How did continental drift lead to the theory of plate tectonics?

MATERIALS

For each student

1 Student Sheet 42.1, "Plate Tectonics Video"

Divers examine an underwater volcanic vent.

PROCEDURE

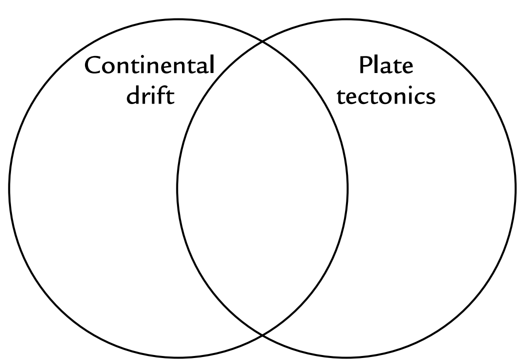
1. To prepare for watching the video, first read Analysis Questions 1–3.
2. Your teacher will provide you with Student Sheet 42.1, "Plate Tectonics Video." It will help you identify some of the important ideas presented in the video. Read the questions on Student Sheet 42.1.
3. Watch the video segments on continental drift and plate tectonics.
4. Answer as many questions on Student Sheet 42.1 as you can.
5. Watch the video segments again.
6. Complete Student Sheet 42.1.

ANALYSIS

1. Why were scientists surprised to find coal in the Arctic?
2. Think about what you learned from the video about where volcanoes are most likely to occur. Based on this information, do you think that the risk of a volcanic explosion at Yucca Mountain is high or low? Explain.
3. **a.** The idea of continental drift eventually led to the modern theory of plate tectonics. To help you remember similarities and differences between these two ideas, create a larger version of the Venn diagram shown below in your science notebook.

   b. Compare continental drift and plate tectonics by recording unique features of each idea in the circle with that label. **Hint:** Think about what you have learned about these ideas in the last few activities.

   c. Record features that are common to both these ideas in the space that overlaps.



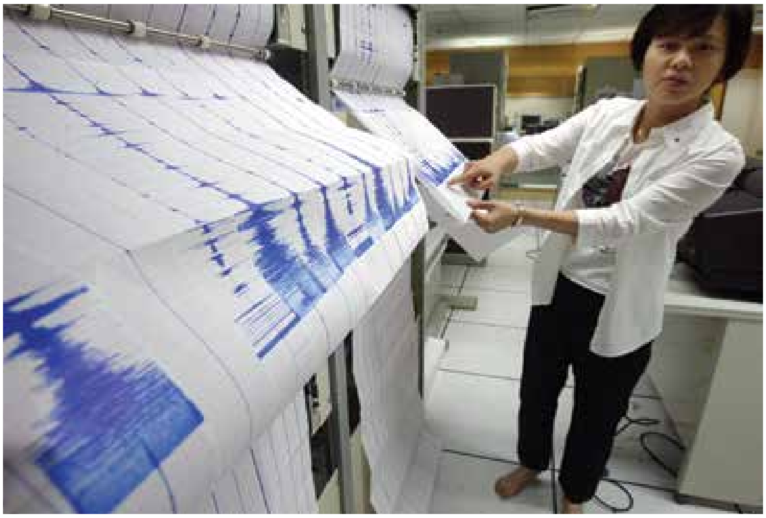
43 Measuring Earthquakes

The earth's plates continue to move. Today, the plate that includes North America is moving away from the plate that includes Europe at a rate of about two centimeters (cm) each year. Moving these huge plates takes lots of energy. Some of this energy causes large sections of underground rock to break and shift position, resulting in an earthquake.

Scientists measure the intensity of an earthquake using a tool known as a **seismograph** (SYZ-mo-graf). A seismograph contains a thin needle-like pen that records the movements detected within the earth on a roll of paper. The lines recorded on the paper are called a **seismogram.**

CHALLENGE

How can a seismograph be used to measure earthquakes?



During earthquakes, rocks shift along a crack that geologists call a fault. *The deep line shown in the middle of the picture on the left shows one of the best-known faults in the United States: the San Andreas Fault in California. Geologists have placed many seismographs along this fault. On the seismogram shown above, the large blue areas were recorded during an earthquake.*

MATERIALS

For each group of four students

1 seismograph model
1 black marker
4 sheets of plain paper
8 toothpicks

For each student

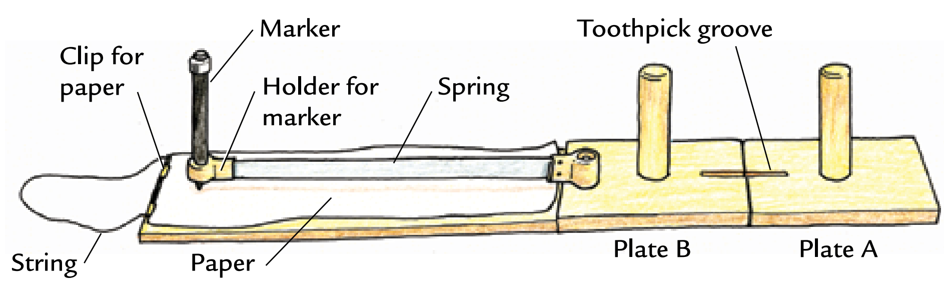
1 pair of safety goggles

SAFETY

Be aware of your surroundings when moving the different parts of the seismograph model. If you have long fingernails, hold the seismograph so that your nails point away from the hands of other group members.

PROCEDURE

1. Work with your group to set up the seismograph model as described in Steps a–d below.



a. Set up the model as shown in the drawing above.

b. Fold a sheet of plain paper in half, lengthwise. Slide the top of the folded sheet into the clips at the end of the paper tray.

c. Remove the cap from the marker and insert it point-down into the holder attached to the end of the spring on Plate B.

d. Check to see if the marker is positioned properly by gently pulling the spring sideways and then releasing it. The marker should leave a curved line on the paper.

2. Decide which person in your group will perform each of the following roles. During the activity, each person will have a chance to perform each role.
    - *Plate A Holder:* Hold the handle of Plate A and press down to keep it steady.
    - *Plate B Holder:* Push Plate B directly away from you, just hard enough so that Plate B slides past Plate A and the toothpick breaks. Don't start pushing until the Data Recorder tells you to start.
    - *Data Recorder:* Slowly pull the string to slide the paper tray away from Plate B (leaving a straight marker line on the paper). After the line is about 3–5 cm long (1–2 inches), tell the Plate B person to start pushing Plate B while you keep slowly pulling the paper tray. You should stop pulling the tray when you have almost reached the end of the paper.
    - *Observer:* Carefully observe the movement of each plate and the resulting seismogram.
3. Push the two plates together and place a toothpick into the groove formed by the two halves.
4. Simulate an earthquake along a plate boundary by completing your roles as described in Step 2.
5. As a group, discuss your observations of the seismograph model, the seismogram, and the force required to break the toothpick. Then record your observations for this trial in your science notebook.

6. Remove any toothpick pieces left in the groove of either Plate A or Plate B, and collect any toothpick pieces that may have fallen onto the table or the floor. Throw these pieces away at the end of the activity.

7. Remove the folded paper from the clip and turn it to the blank side. Insert the paper back into the clip with the blank side face up.

8. Keep the same roles and repeat Steps 3–6 one more time.

9. Now, replace the folded sheet of paper with a new sheet. Switch the roles among your group members and repeat Steps 3–8 until every member of your group has pushed Plate B two times.

10. Unfold the 4 sheets of paper so that all of the recorded data can be seen at the same time. Compare the 8 seismograms. Discuss your observations with your group.

ANALYSIS

1. What similarities and differences did you observe among your group's 8 seismograms?

2. **a.** What did each half of the seismograph model represent?

   b. What did the toothpick represent? (**Hint:** Reread the introduction to this activity.)

   c. When did an "earthquake" occur? It occurred when:

   - the Data Recorder began pulling the paper tray.
   - Plate B was first pushed.
   - the toothpick broke.

   d. What type of plate movement did you simulate?

   - plates colliding
   - plates sliding past each other
   - plates pulling apart

3. Describe what the seismogram looked like:

   a. when there was little or no movement.

   b. when the toothpick broke.

4. This activity modeled an earthquake occurring along a plate boundary. What do you think are the strengths and weaknesses of this model?

44 Mapping Plates

As you've learned, some of the earth's lithospheric plates are slowly sliding past each other, some plates are slowly colliding, and some plates are slowly moving apart. Both earthquakes and volcanoes occur more frequently along such plate boundaries.

CHALLENGE

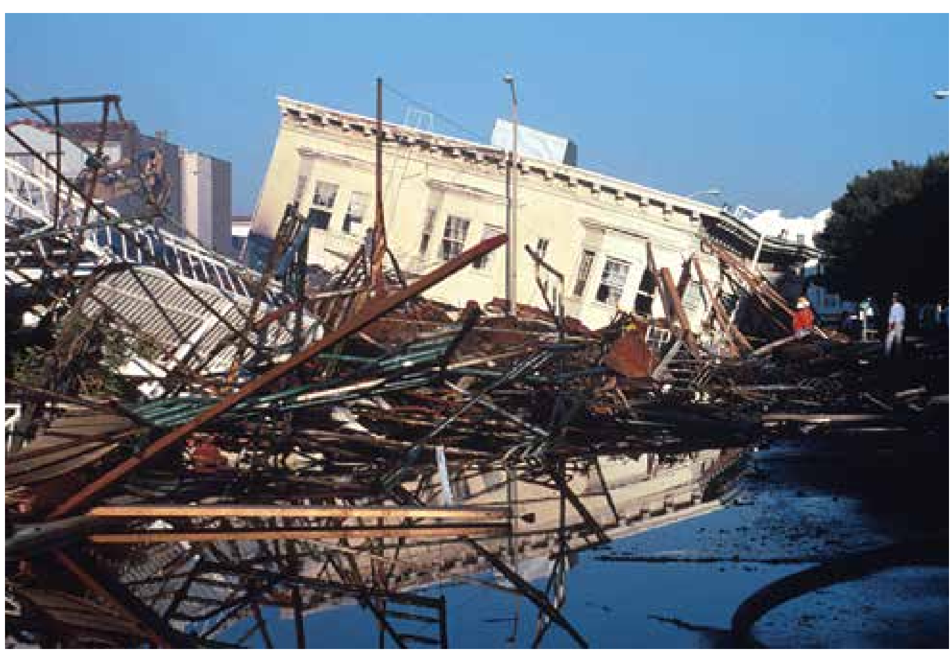
How can you use earthquake and volcano data to map the earth's plates?

MATERIALS

For each student

- 1 **Student Sheet 44.1, "Anticipation Guide: Mapping Plates"**
- 1 **Student Sheet 44.2, "Plate Boundaries"**
- 1 **light-colored pencil (such as yellow)**
- 1 **dark marker (such as purple)**

The result of an earthquake



PROCEDURE

Use Student Sheet 44.1, "Anticipation Guide: Mapping Plates," to prepare you for the following activity.

1. Use a light-colored pencil to color in the continents on Student Sheet 44.2, "Plate Boundaries."
2. Use a dark-colored marker to trace the dashed plate boundary lines on Student Sheet 44.2.
3. The dark lines show the major plates. But if you look carefully, you will notice that the boundaries of the South American plate are missing!
4. To find the missing *eastern* boundary of the South American plate, plot the locations of the earthquakes and volcanoes listed in Table 1, below, on Student Sheet 44.2.

Table 1: Earthquakes and Volcanoes in the Atlantic Ocean

Name and Location	More Information	Location on Map
Earthquake in northern Atlantic Ocean	Occurred on 6/12/01; magnitude 5.4	13 J
Earthquake in northern Atlantic Ocean	Occurred on 4/14/02; magnitude 5.1	13 K
Earthquake in northern Atlantic Ocean	Occurred on 7/31/02; magnitude 5.4	14 K
Earthquake in the Atlantic Ocean	Occurred on 9/17/05; magnitude 4.8	15 L
Underwater volcano in southern Atlantic Ocean	Ship captain reported last known eruption in 1836	16 L
Earthquake in southern Atlantic Ocean	Occurred on 3/7/01; magnitude 6.0	16.5 L/M*
Ascension Island (volcano)	Summit of a stratovolcano; no recent eruptions	16 M
Earthquake in southern Atlantic Ocean	Occurred on 8/24/00; magnitude 5.5	16 O
Tristan da Cunha island volcano	Shield volcano; last known eruption in 2004	16 P
Bouvet Island (volcano)	Ice-covered shield volcano; may have last erupted in 50 B.C.	17 R

*Between 16 and 17, and between L and M

5. Complete this missing eastern boundary by using a dark-colored marker to draw a line connecting the earthquakes and volcanoes you have plotted. **Hint:** Work from top to bottom.

6. Now, to find the missing *western* boundary of the South American plate, plot the locations of earthquakes and volcanoes listed in Table 2, below, on Student Sheet 44.2.

Table 2: Earthquakes and Volcanoes in Central and South America

Name and Location	More Information	Location on Map
Nevado del Ruiz volcano, Colombia	Composite volcano; last major eruption in 1991	10 K
El Misti volcano, Peru	Composite volcano; last major eruption in 1874	9.5 M*
Earthquake in Atacama region, Chile	Occurred in 1922; magnitude 8.5	10.5 N**
Cerro Azul (Quizapu) volcano, Chile	Composite volcano; last major eruption in 1967	10 O
Earthquake near Valdivia, Chile	Occurred in 1960; magnitude 9.5	10 P
Villarrica volcano, Chile	Composite volcano; last major eruption in 2005	10 Q
Monte Burney volcano, Chile	Composite volcano; last major eruption in 1910	10 R

*Between 9 and 10
**Between 10 and 11

7. Complete this missing western boundary using a dark-colored marker to draw a line connecting the earthquakes and volcanoes you have plotted. **Hint:** Work from top to bottom and left to right.

8. Discuss with your partner how the shapes of the continents compare with the shapes of the plates.

9. Use Table 3, below, to help you label some of the plates with their proper names.

Table 3: Some Major Plates

Name of Plate	General Direction of Movement
African	northeast
Antarctic	southeast
Australian	northeast
Eurasian	east
Indian	northeast
North American	west
Pacific	northwest
South American	northwest

10. Use the information in Table 3 to draw an arrow on each of these plates showing the general direction of its movement.

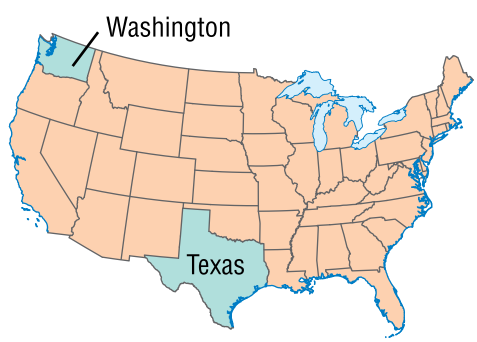
ANALYSIS

1. Are the sizes and shapes of the continents the same as the sizes and shapes of the plates? Support your answer with a specific example from Student Sheet 44.2.

2. Look again at Table 2, "Earthquakes and Volcanoes in Central and South America," on the previous page. In terms of geological time, would you consider these volcanoes and earthquakes to have occurred recently or a long time ago? Explain.

3. What is the relationship between earthquakes, volcanoes, and plate boundaries?

4. In Activity 36, "Storing Waste," you learned that Nevada has the fourth highest number of earthquakes per year in the U.S. Which state would you predict to have a higher risk of earthquakes: Washington or Texas? Why?



5. In Activity 40, "The Continent Puzzle," the country of India was a separate puzzle piece. Use the information on Student Sheet 44.2 to help you explain why.

EXTENSION

On Student Sheet 44.2, you labeled the name and direction of movement for eight major lithospheric plates. Visit the *Issues and Earth Science* page of the SEPUP website for links to sites that show both the name and direction of movement of the remaining plates. Use this information to label seven more plates on Student Sheet 44.2.

45 Understanding Plate Boundaries

READING

The map below shows the locations of earthquakes and volcanoes on the earth's surface. Today, many of the world's most active volcanoes are located around the edges of the Pacific Ocean, and are often referred to as the "Ring of Fire." You may notice that both volcanoes and earthquakes tend to be concentrated in particular areas. The theory of plate tectonics helps explain this pattern.

CHALLENGE

How does the theory of plate tectonics help to explain the locations of earthquakes, volcanoes, and mountain ranges?

MATERIALS

For each student

1 **completed Student Sheet 44.2, "Plate Boundaries"**

1 **Student Sheet 45.1, "Directed Reading Table: Understanding Plate Boundaries"**

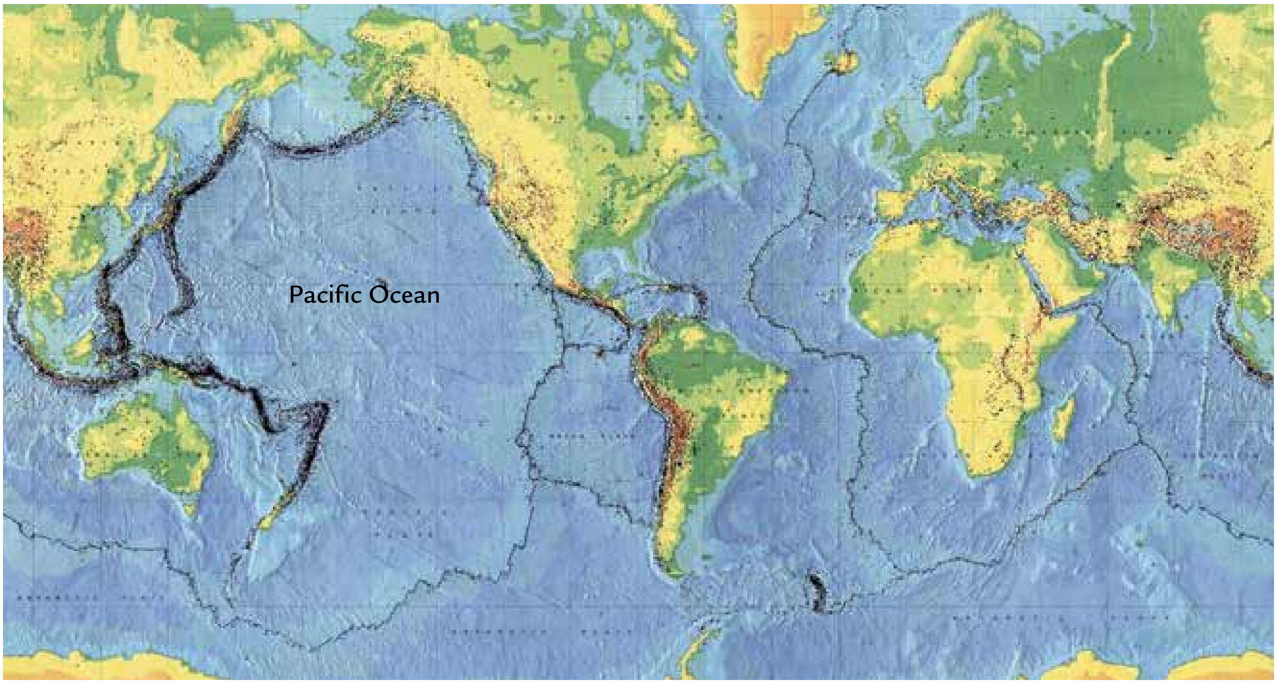


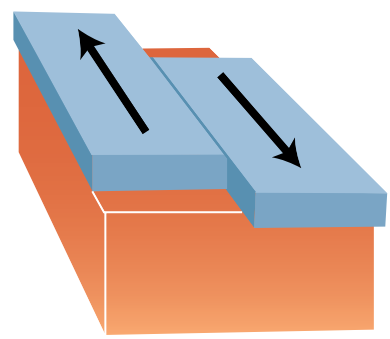
FIGURE 1: MAP OF RECENT EARTHQUAKES AND VOLCANOES ON EARTH
Black dots mark the locations of individual earthquakes and volcanoes.

READING

Use Student Sheet 45.1, "Directed Reading Table: Understanding Plate Boundaries," to guide you through the following reading.

Plate tectonics is the theory that the earth's lithosphere is broken into plates that are in constant motion. The edges of these plates may be sliding past each other, spreading apart, or colliding. Over geological time, important processes—such as the formation of mountain ranges, earthquakes, and volcanoes—take place along the boundaries where these plates meet.

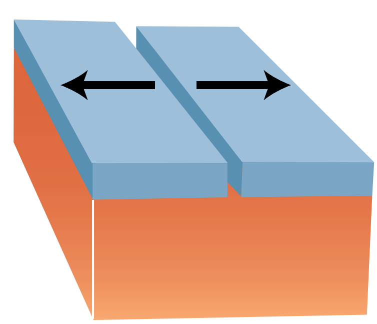
Sliding Plates



Geologists call the region where two plates are sliding past each other a **transform** boundary. Earthquakes are common along transform boundaries. There is a lot of pressure between the plates as they try to move past each other, and this pressure is only released when large pieces of rock along the boundary crack or shift their position. People can sometimes feel the vibrations caused by these movements and call them earthquakes.

In Activity 44, "Mapping Plates," you recorded the overall movement of several large plates. Each plate may have different types of boundaries along different parts of its edge. A transform boundary is located between a part of the Pacific plate and a part of the North American plate, along the western edge of California. This is an area known for its many earthquakes, as you can see in Figure 1, "Map of Recent Earthquakes and Volcanoes on Earth." On its eastern edge, the North American Plate has a divergent boundary.

Spreading Plates



The place where plates are spreading apart is called a **divergent** (dy-VER-junt) boundary. Volcanoes as well as earthquakes are common along divergent boundaries. As the plates pull apart, the lithosphere thins and molten magma from the earth's mantle erupts onto the surface, forming new lithosphere (See Figure 2, on the next page). Over time, the lava from these volcanoes can build

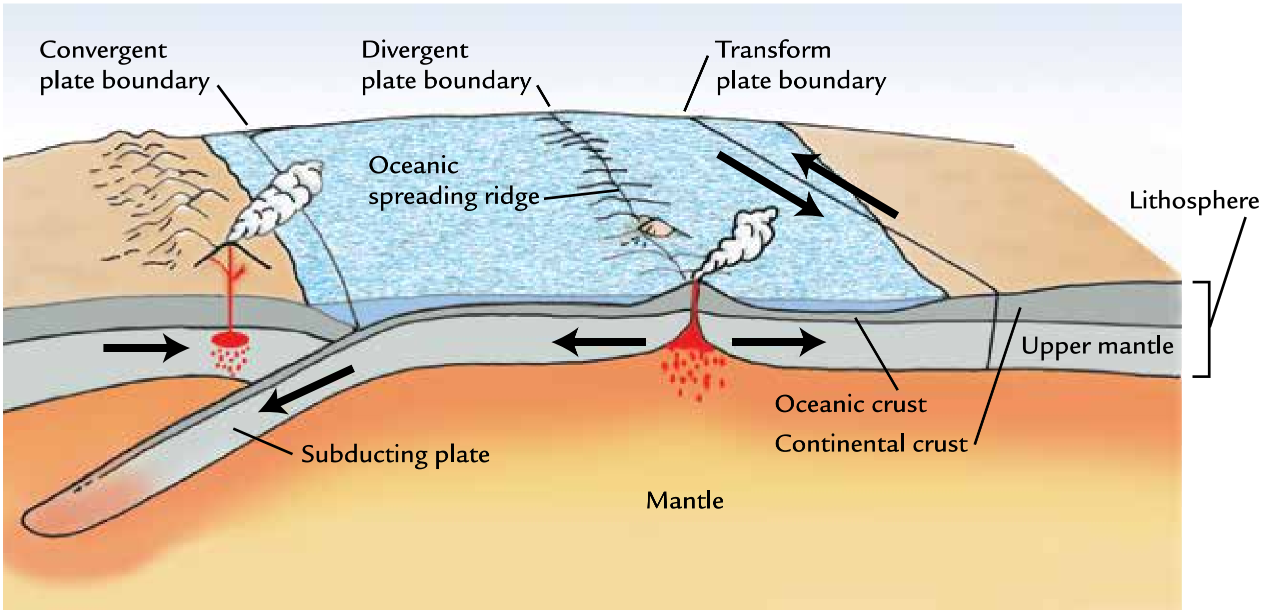


FIGURE 2:
TYPES OF PLATE
BOUNDARIES

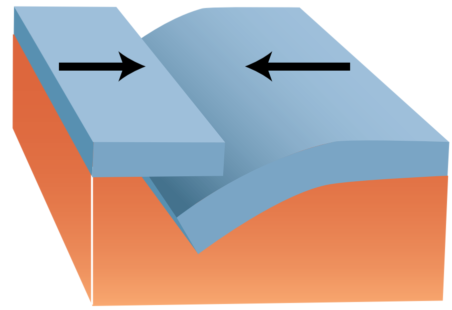
up and form volcanic mountains. You read about such mountains in Activity 38, "Beneath the Earth's Surface."

Sometimes, divergent boundaries are located under the ocean, and large underwater volcanic mountains can form. The plate boundaries seen along the middle of the Atlantic Ocean are an example of an underwater divergent boundary.

Colliding Plates

Colliding plates create **convergent** (kun-VER-junt) boundaries. What happens along a convergent boundary depends on the type of lithosphere at the edge of each of the colliding plates. The earth's lithosphere—which includes the crust and solid upper mantle—varies over the surface of the earth. This is partly due to differences in the thickness of the earth's crust. The crust that makes up the oceans is generally thinner than the crust that makes up the continents. Oceanic crust is usually about 10 kilometers (km) thick, while continental crust ranges from 20 to 80 km thick. For this reason, the lithosphere is about 100–150 km thick under the ocean, and up to 300 km thick at some continents. Despite being thinner, oceanic lithosphere is denser than continental lithosphere because its crust is made up of denser rocks, such as basalt.

When continental and oceanic lithosphere collide, the less dense continental lithosphere usually rides up over the oceanic lithosphere, which goes down into the mantle and is destroyed. (See Figure 2, above.)



The process of one plate moving below another plate is known as **subduction** (sub-DUK-shun). Both earthquakes and volcanoes are common along subduction zones. The volcanic mountains that you plotted along the western coast of South America in Activity 44, "Mapping Plates," are a result of the oceanic lithosphere of the Pacific plate being subducted below the continental lithosphere of the South American plate. The March, 2011 earthquake off the coast of Japan was also a result of the subduction of the oceanic Pacific plate beneath a continental plate. This is also happening in the Pacific northwest as the Juan de Fuca plate is moving under the North American plate. Subduction also occurs when two sections of oceanic lithosphere collide.

When two sections of continental lithosphere collide, the lithosphere tends to crumple and be pushed upward, forming mountains as well as causing earthquakes. The Himalayan mountains found along the northern border of India were formed when the Indian plate collided with the Eurasian plate. Several of the world's highest mountains, including Mount Everest, are part of the Himalayas and were formed from this collision.

Volcanoes and Plates

Most earthquakes and volcanoes occur along plate boundaries, but there are exceptions. For example, volcanoes formed each of the Hawaiian Islands. Lava from eruptions over hundreds of thousands of years built up the islands. Yet the Hawaiian Islands are located far from any plate boundaries. Hawaii, the "Big Island" at the southwestern end of the island chain, is the only one of those islands that still has an active volcano. A new island called Loihi has begun to form beneath the ocean southwest of the Big Island. But don't start making vacation plans to visit Loihi. Scientists predict it will rise above the ocean's surface in about one million years.

The explanation for the formation of the

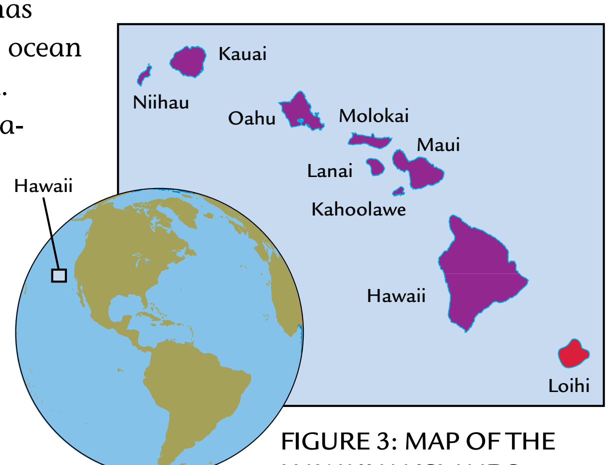


FIGURE 3: MAP OF THE HAWAIIAN ISLANDS

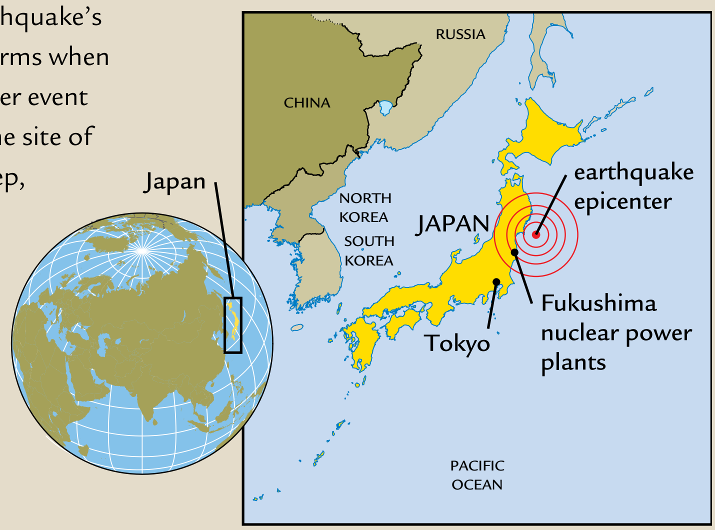
The 2011 Earthquake and Fukushima Nuclear Accident in Japan

ON MARCH 11, 2011, a huge earthquake rocked Japan. This earthquake had a magnitude of 9.0 and was centered 70 km (43 mi) off the coast of the largest Japanese island, Honshu. More than 15,000 people were killed, more than 5,000 were injured, and more than 330,000 structures, including buildings, roads, bridges, and railways, were destroyed. The cost of this earthquake is estimated at hundreds of billions of U.S. dollars.

Most of the deaths, injuries, and damage were caused by a tsunami, rather than the earthquake's shaking. A tsunami is a large wave that forms when an earthquake, volcano, landslide, or other event moves a very large amount of water. At the site of an earthquake where the water is very deep, the wave might be only a few inches high. But as the wave moves into shallower areas closer to shore, the very large amount of water forms a high wave. At its highest, the height of the wave from the Japanese earthquake reached nearly 38 m (125 ft).

The earthquake led to a serious accident at a nuclear power plant located in Fukushima, on Honshu. Three of the six nuclear reactors in the plant overheated when the cooling system failed. This caused a nuclear fuel meltdown and explosions. Several workers were killed, and more were exposed to radiation. Of concern to people outside the plant, radioactive material was released into the air and water. The long-term effects of radiation released to the environment by the accident are not yet known. The greatest fear is that exposure to radiation will lead to increased deaths from cancer.

Although nuclear waste does not explode, the accident in Japan has increased concern in the United States and elsewhere about all aspects of nuclear safety.



This damaged building at the Fukushima Daiichi nuclear power plant was photographed one year after the earthquake and tsunami.

Hawaiian island chain is still a subject of active research. One theory suggests that extremely hot material in a region called a hot spot rose to the surface from the deep mantle. According to this theory, movement of the Pacific plate carried each of the islands toward the northwest, away from the hot spot. Other ideas are based on the properties of plates. For example, volcanoes might form when thin or cracked areas of the lithosphere allow hot material from the upper mantle to break through.

ANALYSIS

1. Describe two ways in which the movement of lithospheric plates can result in the formation of mountains.

2. On Student Sheet 44.2, "Plate Boundaries," you drew the boundaries of large, lithospheric plates. Use information from this reading to identify and label:

   a. a transform boundary

   b. a divergent boundary

   c. a convergent boundary

3. Yucca Mountain is located close to H6 on Student Sheet 44.2. Which type of boundary is closest to it?

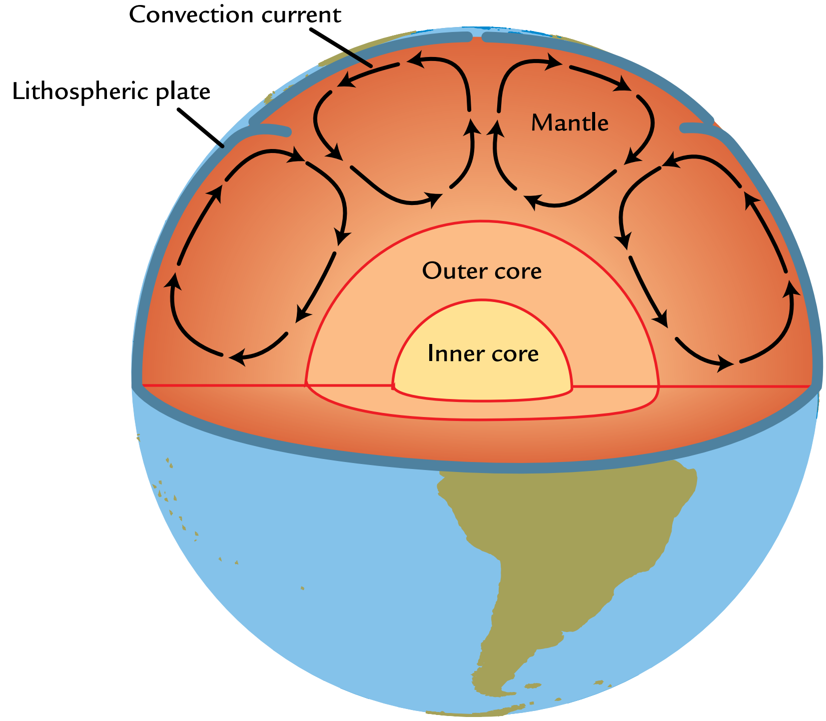
4. Of the three different types of rocks—igneous, metamorphic, and sedimentary—which type of rock would you expect to find along a divergent plate boundary? Explain.

46 Convection Currents

Scientists don't know exactly what drives plate motion. One theory is that there are convection currents within the earth's mantle. **Convection** occurs when there is a temperature difference within a substance like magma, causing it to move in a circular pattern shown in the diagram below). This convection of the magma within the mantle is believed to cause plate movement. In this activity, you will investigate how differences in temperature can cause substances like magma to move.

CHALLENGE **How do differences in temperature cause a convection current?**

MANTLE CONVECTION



MATERIALS

For the class

supply of warm water
supply of cold water

For each group of four students

- 2 9-oz. plastic cups
- 1 plastic syringe
- 1 plastic cup with circular depression
- 1 small vial with 2-holed cap
- 1 bottle of red food coloring
- paper towels and/or a sponge

PROCEDURE

CAPPED VIAL IN CUP

1. Fill two 9-oz. plastic cups, one with warm water and the other with cold water.
2. Snap the small vial (cap-side up) into the base of the plastic cup that has a circular depression, as shown at left.
3. Gently remove the cap and place 1 drop of food coloring into the bottom of the vial. Carefully and firmly re-cap the vial with the 2-holed cap.
4. Use the syringe to carefully fill the vial with about 5 mL of warm water. Gently tap the vial to remove any air bubbles.
5. Cover both of the holes in the 2-holed cap with two fingers and have one person in your group slowly add cold water to the set-up until it is almost full.
6. Remove your fingers and observe what happens from both the side and the top.
7. Record your observations as Trial 1 in your science notebook. Use arrows to sketch the movement of the colored water.
8. After a few minutes, carefully remove the vial from the cup. Describe the contents of the vial in your science notebook.
9. Empty and rinse the vial, the cap, and the cup.
10. Repeat Steps 3–9, but this time use *cold* water in Step 4 and *warm* water in Step 5. Record your observations as Trial 2.

ANALYSIS

1. **a.** Did both trials result in the movement of water? Why or why not? Discuss your ideas with your group.

   b. What do you think is necessary for a convection current to form?

2. Compare the results of your two trials. When warm and cold water are mixed, what happens:

   a. to the warm water?

   b. to the cold water?

3. Imagine that hotter magma is lying beneath an area of cooler magma deep in the mantle. What do you predict will happen? Be as specific as you can and explain your reasoning.

4. What do scientists believe causes plates to move?

47 Spreading Plates

The earth's plates move very slowly—even the fastest move less than 10 centimeters per year. But they have also been moving for millions of years. As a result, their motion has changed the surface of the earth. In this activity, you will further explore what happens to the earth's surface as two plates move apart from each other.

CHALLENGE

What happens when the earth's plates move apart over time?

The Red Sea was formed by spreading between the African and Arabian plates.

MATERIALS

For each pair of students

access to a computer

For each student

1 Student Sheet 47.1, "Spreading Plate Observations"

PROCEDURE

1. Set the direction for Plate 1 to move by clicking on the arrow pointing left (⟵).

   Note: You will explore the other directions in the next activity.

2. On Student Sheet 47.1, "Spreading Plate Observations," record the directions in which Plate 1 and Plate 2 will move.
3. Click on the SEE PLATES OVER TIME button at the bottom of the screen. You should now see a LEGEND on the bottom left of the screen. Read the legend so that you know what each symbol means.
4. Use the PICK TIME button to set the simulation to run for 10 years.
5. Click on the RUN button to begin the simulation and then carefully observe what happens.
6. Record your observations on Student Sheet 47.1.
7. Reset the screen by clicking on the RESET TIME button.
8. Repeat Steps 4–7, but run your simulation for 100 years.
9. Repeat Steps 4–7, but run your simulation for 1,000 years.
10. Repeat Steps 4–7, but run your simulation for 1 million years.
11. Repeat Steps 4–7, but run your simulation for 5 million years.
12. Repeat Steps 4–7, but run your simulation for 20 million years.

ANALYSIS

1. In the simulation, you saw water collect between the spreading plates: where does this water come from?

2. In the simulation, how many years passed before you observed major changes to the earth's surface?

3. There are seven continents on earth today. How many do you predict there will be:

   a. in 1,000 years? Explain.

   b. in 20 million years? Explain.

4. a. List at least three things that can happen as plates spread apart.

   b. Place these events in order by numbering them.

48 Other Types of Plate Motion

Plates can move in different directions. In the last activity, you explored what happens to the earth's surface as two plates move apart. Plates can also collide or slide past each other. Find out how these plate motions are similar to or different from spreading plates.

CHALLENGE

What happens as the earth's plates collide or slide past each other?

MATERIALS

For each pair of students

access to a computer

For each student

1 **Student Sheet 48.1, "Other Plate Directions"**

The movement of the earth's plates has changed the surface of the earth. The Himalayan mountains, right, were formed by the collision of two plates.

PROCEDURE

1. Choose a direction in which Plate 1 will move.

   Note: Do not repeat Activity 47, "Spreading Plates," by selecting the arrow pointing left (⟵).

2. On Student Sheet 48.1, "Other Plate Directions," circle the directions in which Plate 1 and Plate 2 will move and record the type of boundary (either convergent, divergent, or transform) that you are investigating.
3. Click on the SEE PLATES OVER TIME button. If you are investigating a convergent boundary, record the type of lithosphere (continental or oceanic) on the same line of Student Sheet 48.1 as the Type of Boundary.
4. Use the PICK TIME button to set the simulation to run for 20 million years.
5. Click on the RUN button and observe what happens. You may want to repeat the simulation or run it for different periods of time so that you can make better observations.
6. Record your observations on Student Sheet 48.1.
7. If you selected a convergent boundary, click on the button labeled WHAT IF TWO OCEANIC PLATES COLLIDE? and repeat Steps 4–6. If you did not select a convergent boundary, go on to Step 8.
8. Reset the simulation by clicking on the HOME button.
9. Repeat Steps 1–8, but select a new direction in which Plate 1 will move.

ANALYSIS

1. Why do the geological processes that occur at convergent boundaries vary?
2. In this activity, which type of boundary modeled:
   a. the formation of the Himalayan mountains?
   b. the formation of Greenland, a volcanic island country in the northern Atlantic Ocean?

3. In your science notebook, make a table like the one below. Identify the scientific term for each type of plate boundary and then place a ✔ to identify what is likely to happen at each type of plate boundary.

Comparing Plate Motion

Types of Plate Motion	Scientific Term for Boundary Type	Earthquakes	Volcanoes	Mountain Formation
Colliding				
Sliding				
Spreading				

4. Imagine that your parents ask you what you are learning in school. In your own words, explain:

   a. the theory of plate tectonics and

   b. how earthquakes, volcanoes, and mountain formation are related to plate tectonics.

   Be as specific as you can.

5. **Reflection:** Do you think the world's continents and oceans will look the same in the future as they do now? Why or why not?

EXTENSION

In this activity, you investigated the movement of plate boundaries in which the edges of the plate margin were straight. Find out what happens along a transform boundary when there is a bend in the plate. On the home page of the SEPUP Plate Motion computer simulation, click on the button that says EXTENSION: BENT PLATE BOUNDARIES. How do changes to the earth's surface at the bent transform boundary compare to the straight transform boundary you investigated in this activity?

49 Comparing Site Risk

In Activity 36, "Storing Waste," you learned about the nuclear waste problem. You also looked at evidence about Yucca Mountain, which has been considered as a possible site for storing nuclear waste. Based on current recommendations by experts, it is likely that the U. S. will search for other sites for deep storage of waste, either in addition to or instead of the Yucca Mountain site.

Imagine the year is 2030, and the United States is looking for a long-term storage sites. Use what you have learned in this unit to help you evaluate eight sites.

CHALLENGE

Which location would you recommend for further study as a possible site for storing nuclear waste?

MATERIALS

For each student

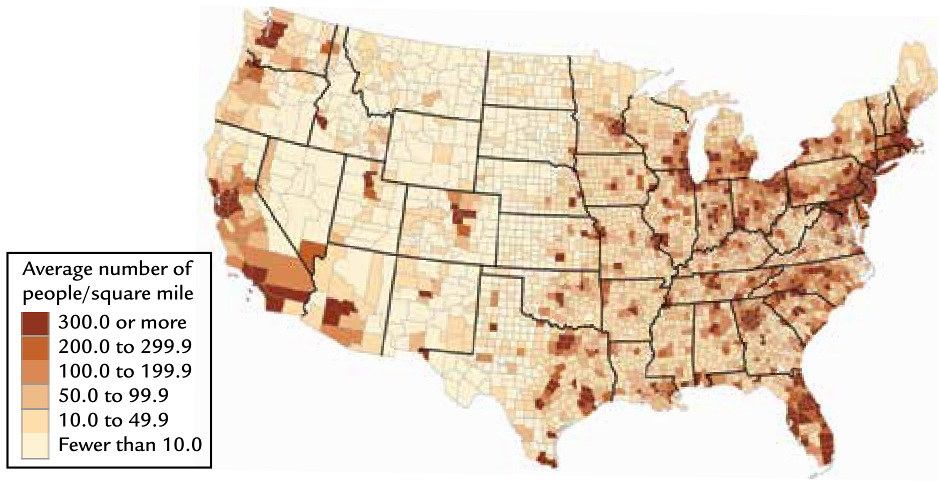
- 1 **Student Sheet 49.1, "Eight Proposed Waste Sites"**
- 1 **Student Sheet 49.2, "Discussion Web: Evaluating Site Risk"**
- 1 **Student Sheet 49.3, "Comparing Eight Proposed Sites"**

This chamber 700 meters below the surface near Carlsbad, New Mexico is part of a research project to study salt beds as a location for the storage of highly radioactive nuclear waste.

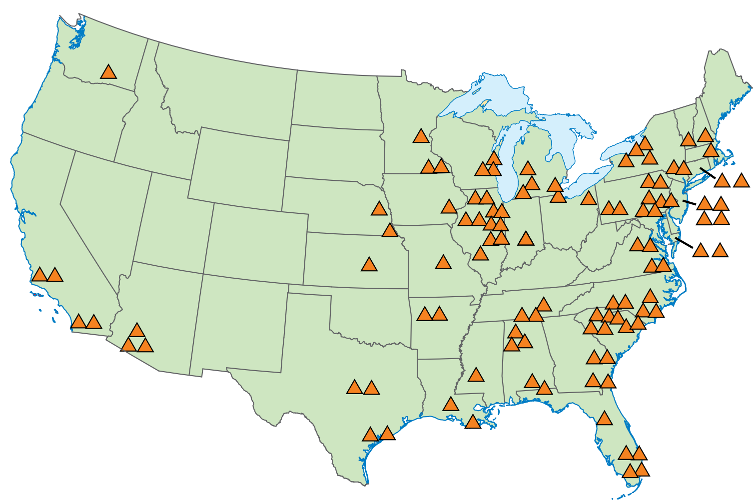
PROCEDURE

1. Work with your group of four to complete this activity. Remember to listen to and consider the ideas of the other members of your group. If you disagree with others in your group, explain why you disagree.
2. Examine Maps 1 and 2, on the following page. These maps show the population density and location of nuclear reactors around the United States. Discuss how this information might influence your choice of a site.
3. Examine Maps 3 and 4, and compare the risk of earthquakes and volcanoes in the United States. Discuss how this information might influence your choice of a site.
4. Examine Maps 5 and 6. Map 5 shows areas of stable granite. Map 6 shows where there are major sources of underground water. Discuss how this information might influence your choice of a site.
5. Your teacher will distribute Student Sheet 49.1, "Eight Proposed Waste Sites," and will assign your group to evaluate one of the sites.
6. Complete Student Sheet 49.2, "Discussion Web: Evaluating Site Risk," to sort the evidence about your site.
7. Present your group's analysis of your site to the class.
8. After each group has made a presentation, discuss with your group which two sites you recommend for further study.

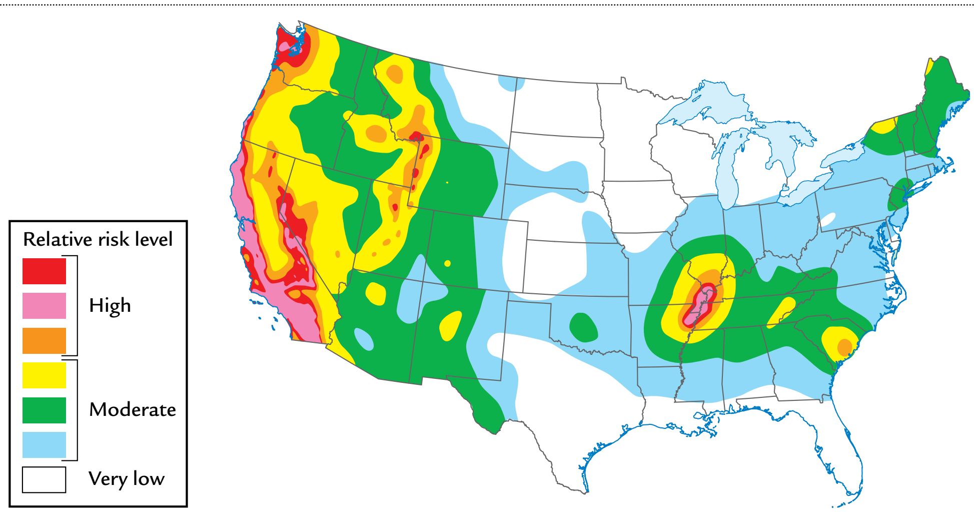
MAP 1:
POPULATION
DENSITY BY COUNTY



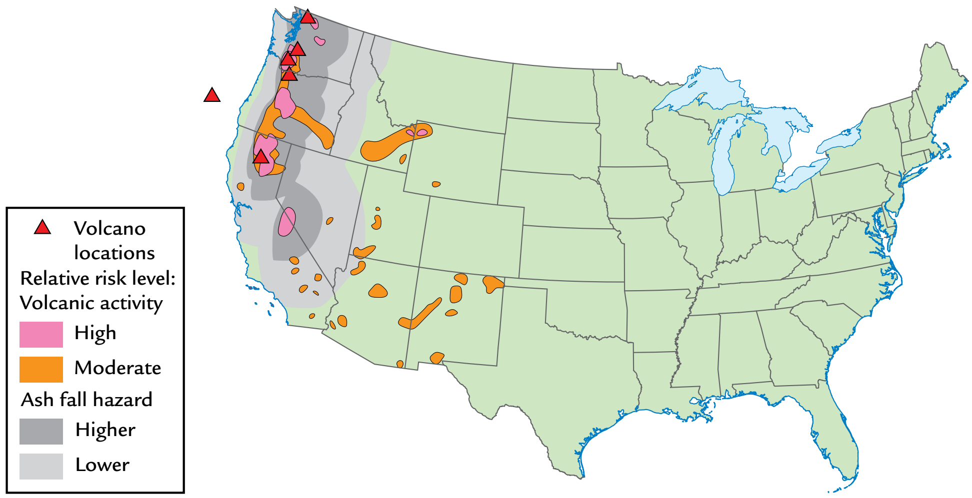
MAP 2:
U.S. LOCATIONS
OF NUCLEAR POWER
REACTORS



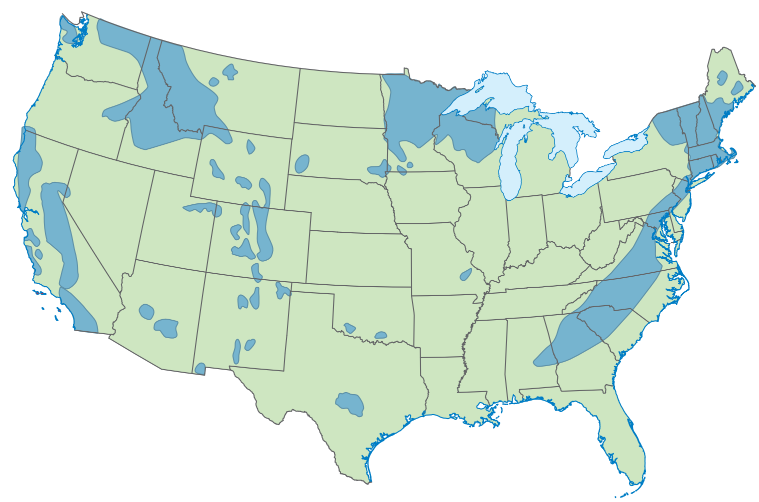
MAP 3:
U.S. EARTHQUAKE
HAZARDS



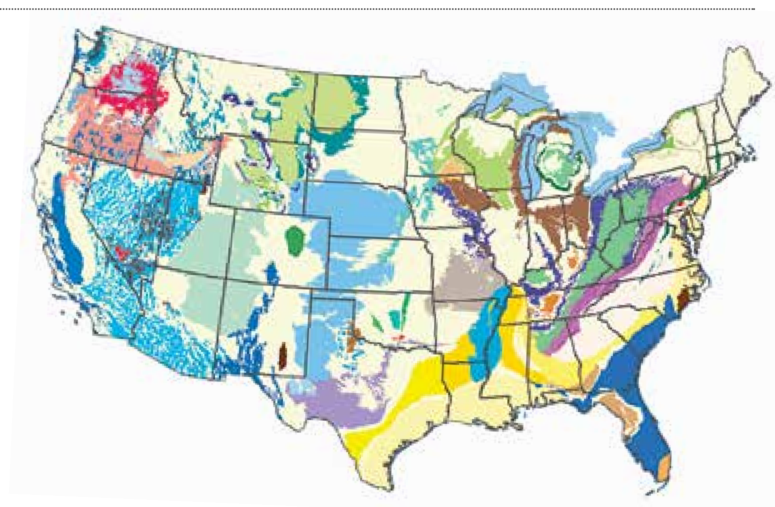
MAP 4:
U.S. VOLCANO
HAZARDS



MAP 5:
GRANITE OUTCROPS
IN THE U.S.



MAP 6:
U.S. AQUIFER MAP



ANALYSIS

1. What scientific evidence and risks should be considered when selecting a site for storing nuclear waste?

2. What role do you think people in the community should have when a site near them has been suggested for storing nuclear waste?

3. Would you select one of the eight sites, or would you suggest a different site?

    a. State the site you would choose.

    b. Support your decision with as many pieces of evidence as you can.

    c. Discuss the trade-offs of your decision.

4. **Reflection:** Have your ideas about where to store nuclear waste changed during this unit? How?