



What happens when a volcano erupts? 

Some volcanic eruptions are quiet. The lava flows out of the volcano and over Earth's surface. Other eruptions are explosive and send gases, lava, and pieces of rock high into the air.

- 1 Read and complete a lab safety form.
- 2 Cover your work area with **newspaper**. Place a **small plastic cylinder** in the center of the paper.
- 3 Use a **funnel** to pour one heaping spoonful of **baking soda** into the cylinder. Then add one spoonful of **small plastic beads** and five of the **larger plastic beads** to the cylinder.
- 4 Pour about 50 mL of **white vinegar** into a small **beaker**.
- 5 Pour the vinegar into the cylinder. Record your observations in your Science Journal.



Think About This

1. **Describe** What happens when you add the vinegar to the baking soda? How are the different-sized beads erupted?
2.  **Key Concept** How do you think a volcano can change Earth's surface?

Earthquakes

An **earthquake** is the vibrations caused by the rupture and sudden movement of rocks along a break or a crack in Earth's crust. Earthquakes occur every day on Earth. The strong shaking of Earth's surface can damage both natural features and human-made structures.

Fault

Earthquakes can occur at faults. A **fault** is a crack or a fracture in Earth's crust along which movement occurs. One place where a fault can exist is at a plate boundary. Tectonic plates do not continually slide past each other along faults. But, because of the convection currents beneath the tectonic plates, forces build up along faults. Eventually, these forces become so great that the rocks on either side of the fault move and slide along the fault, as shown in Figure 8. When this happens, the fault is said to rupture, and Earth's crust moves along the fault, causing an earthquake.



 **Reading Check** What is the relationship between faults and plate boundaries?



Figure 8 Blocks of crust move along the surface at a fault. This is an aerial view of a transform fault in Iran.

 **Visual Check** In which direction are the plates moving?



Earthquake Magnitudes			
Magnitude	Average Number per Year	Typical Fault Length on Surface	Typical Movement on Fault
3	>100,000	15 m	1 mm
4	15,000	100 m	5 mm
5	3,000	800 m	3 cm
6	100	6 km	20 cm
7	20	40 km	1 m
8	2	300 km	6 m

Table 1 Earthquakes occur every day, and there are more than a few major earthquakes each year.

Concepts in Motion Interactive Table

WORD ORIGIN
 magnitude
 from Latin *magnitudo*, means "great bulk or size"

SCIENCE USE v. COMMON USE
 fault
Science Use a fracture in the crust of a planet
Common Use responsibility for wrongdoing or failure

Figure 9 The convergent boundary between the Indian Plate and the Burma Plate (part of the Eurasian Plate) ruptured in 2004. The area of the rupture is indicated in green on the map. Smaller earthquakes have occurred in the purple areas.

Visual Check How does the size of the 2004 earthquake compare to the other earthquakes?

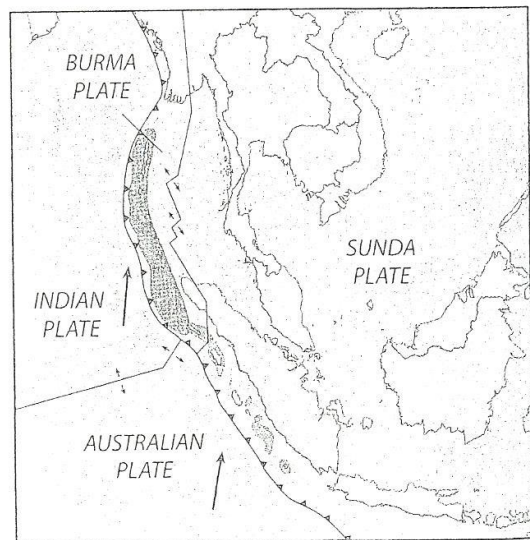
Where Earthquakes Occur

Most earthquakes occur at plate boundaries. Plate boundaries are long and do not rupture all at once. Instead, usually only small segments rupture. As shown in Table 1, small earthquakes occur more frequently than large ones. The size of an earthquake is determined by how much energy is released during the earthquake. This is called **magnitude** and can range from less than one to at least 9.9.

A plate boundary is made up of more than one fault. The boundary covers a large region, and many smaller faults can branch out from the main fault. Faults can be many kilometers from the plate boundary. Earthquakes can occur on these remote faults, just as they do on faults at plate boundaries.

Faults are largest where one plate subducts into the mantle. The strongest and most damaging earthquakes occur at these locations. Higher magnitude earthquakes occur when movement along faults covers large distances. For example, in 2004 the boundary between two plates, shown in Figure 9, ruptured. The earthquake had a magnitude greater than 9 and devastated the country of Sumatra.

Key Concept Check Where do most earthquakes occur?



How Earthquakes Change Earth's Surface

The movement of crust along faults can make mountains, valleys, and other landforms. Different types of movement occur at the three types of plate boundaries. These are illustrated and described in Table 2.


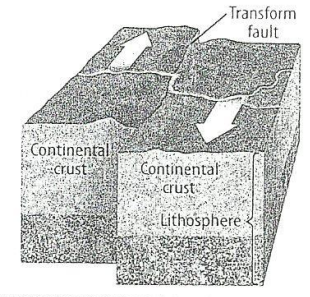
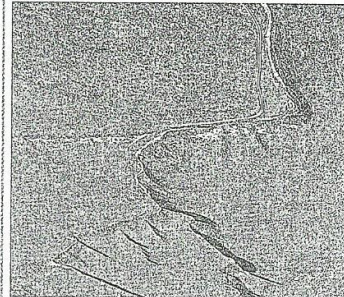
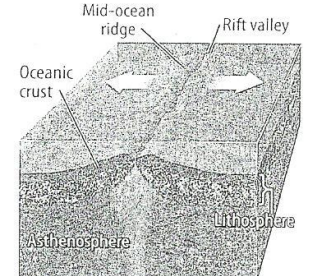

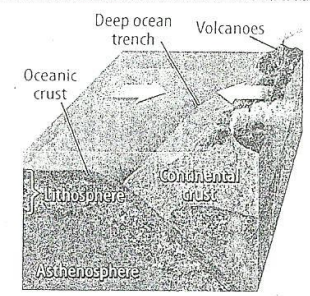

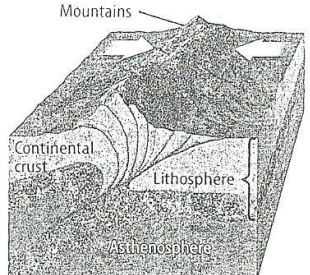

 **Key Concept Check** How are landforms related to plate tectonics?

Plate Boundary	Relative Motion	Example
<p>Transform boundary At a transform boundary, blocks of crust move horizontally past each other. Features that cross the fault, such as streams, are shifted both by plate movement and by earthquakes. Transform faults also are called strike-slip faults.</p>		
<p>Divergent boundary At divergent boundaries between oceanic plates, mid-ocean ridges form, as illustrated to the right. Between continental plates, one side of the fault moves down relative to the other side of the fault. Normal faults form valleys at these boundaries, as shown in the photograph to the right.</p>		
<p>Convergent boundary—subduction zone At these types of boundaries, the plate that does not subduct deforms and crumples as the two plates push toward each other. As the mantle near the subducted plate melts, magma rises and forms a volcanic arc on the plate that does not subduct.</p>		
<p>Convergent boundary—no subduction At these types of boundaries, the edges of both tectonic plates become crumpled and deformed. Because neither plate subducts, blocks of crust slide upward along a complex series of faults called reverse faults. This results in the formation of tall mountains.</p>		




What are three types of fault motion?

A fault is a fracture in Earth's crust along which movement has occurred. There are three main types of faults. Can you model these faults and relate them to the movement at plate boundaries?

1. Read and complete a lab safety form.
2. Obtain a **pair of blocks**. What do the different colors represent? Where is the fault?
3. Line up the rock beds. Model a fault by moving the block above the fault plane down about 5 cm. In your Science Journal, use **colored pencils** to draw and label the positions of the two blocks.
4. Line up the rock beds. Model another fault by moving the block above the fault plane up about 5 cm. Draw and label the positions of the two blocks.
5. Model a third fault by lining up the blocks, then moving one block backward or forward. Do not move the block vertically. Draw and label the positions of the blocks.

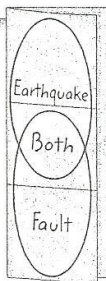


Analyze and Conclude

1. **Cause and Effect** Identify the three types of faults modeled. Along which type of plate boundary does each of these faults occur?
2.  **Key Concept** How are faults related to plate tectonics?

FOLDABLES®

Make a vertical three-tab Venn book. Label it as shown. Use it to compare and contrast earthquakes and faults.



Volcanoes

The temperature inside Earth is hot enough to melt rock. Geologists call *molten rock stored beneath Earth's surface* **magma**. **Lava** is magma that erupts onto Earth's surface. **Volcanoes** are vents in Earth's crust through which molten rock flows. Volcanoes are common on Earth. During the last 10,000 years, more than 1,500 different volcanoes have erupted. Although they are common, volcanoes do not form everywhere.

Where Volcanoes Occur

Most volcanoes form at convergent plate boundaries. Recall that at some convergent boundaries, one plate subducts under another plate. Some rocks contain water within their structure. As the rocks subduct, heat and pressure drive the water out. This water can lower the melting temperature of the mantle. Magma then rises toward the surface and forms volcanoes on the plate that does not subduct. A line of volcanoes forms parallel to the plate boundary directly above the plate that subducted. The volcanoes in Washington and Oregon, such as Mount Rainier, Mount St. Helens, and Mount Hood, formed above the subducting Juan de Fuca Plate.


 **Key Concept Check** Where do most volcanoes form?

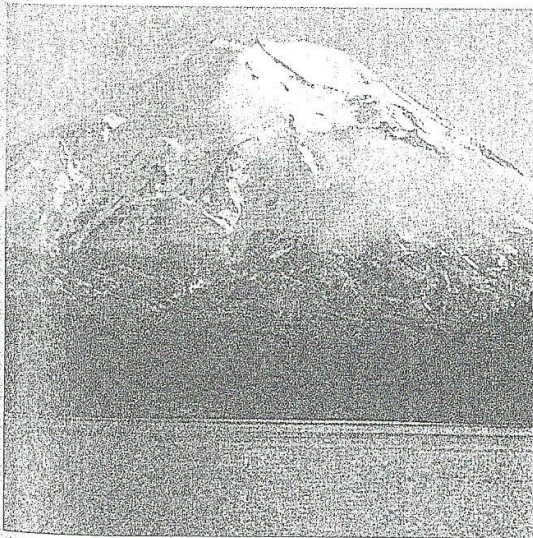
How Volcanoes Change Earth's Surface

Volcanoes are some of Earth's most distinctive landforms. Compared to other mountains, volcanoes can form quickly. Mountains can form over millions of years, but volcanoes can form in hundreds to thousands of years. Sometimes it happens even more quickly. Parícutín volcano, shown in Figure 10, formed within one year.

Volcanoes erupt in two ways. Sometimes, lava can flow over Earth's surface before cooling, hardening, and becoming solid rock, as pictured in Figure 11. This is called a lava flow. Lava flows can be more than 10 km long and, over time, can cover large areas.

At other times, volcanoes can erupt explosively. Much of Mount St. Helens, shown in Figure 12, was destroyed during an eruption in 1980. This kind of eruption can produce tiny pieces of glass made from solidified lava. These pieces are called ash and can be blown high into the atmosphere. When the ash falls back to Earth's surface, it can cover vast areas. Ash from Mount St. Helens in Washington fell as far away as Minnesota and Oklahoma.

 **Reading Check** How can volcanoes change Earth's surface?





 **Figure 10** Within one year, Parícutín volcano in Mexico grew 365 m above its surroundings.

Figure 11 Lava flows can slowly cover the region surrounding a volcano. 

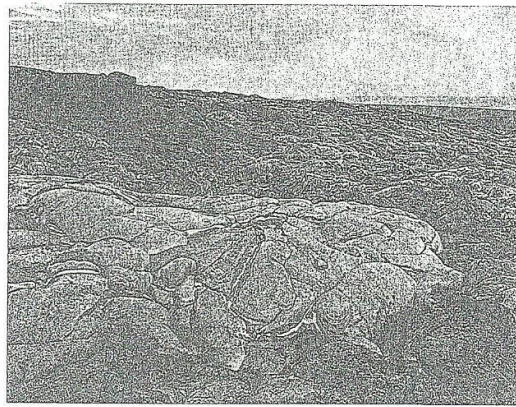

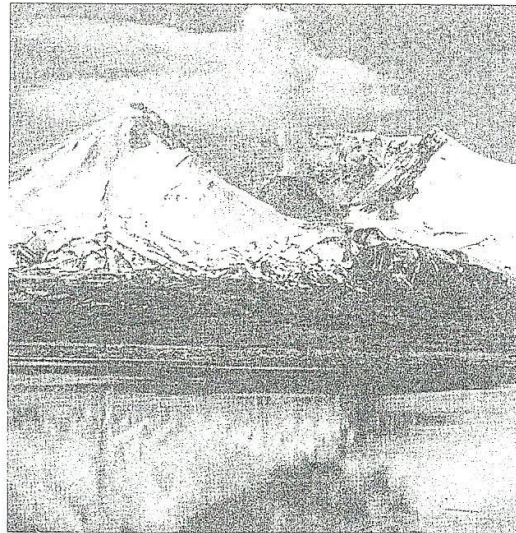
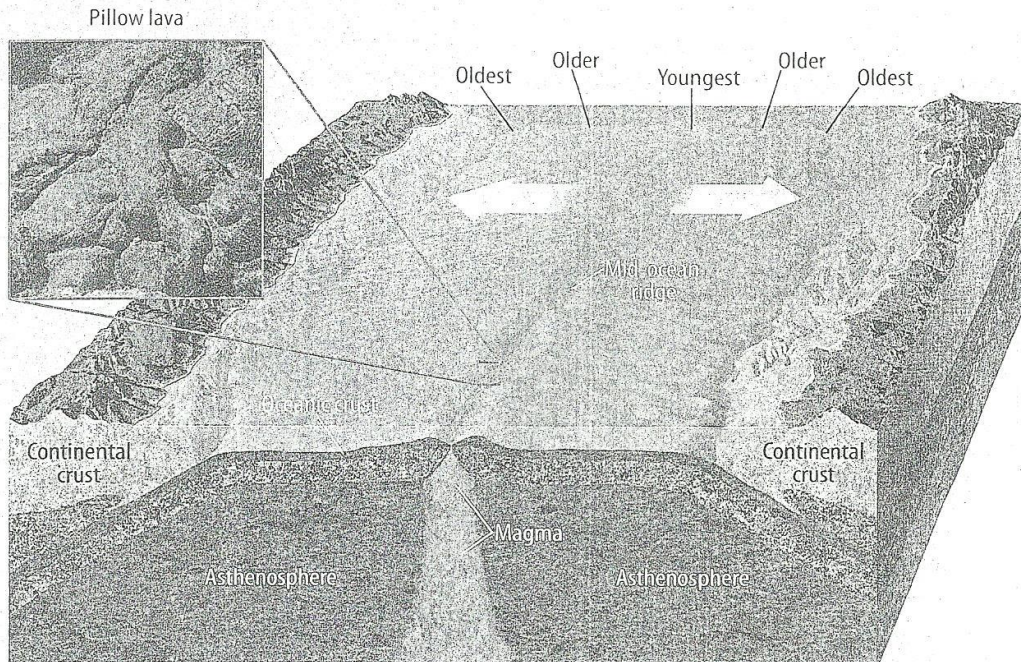


Figure 12 The image on the left shows Mount St. Helens before it erupted. In 1980, the volcano's explosive eruption destroyed part of the mountain, as shown in the image on the right. 



Formation of Oceanic Crust

Figure 13 At a divergent plate boundary, magma rises between two plates and forms new crust. A long mountain range called a mid-ocean ridge forms at a divergent boundary beneath the ocean.



Ocean Basins

Lava does not erupt only from volcanoes on land. Recall that the land masses that make up North America and Europe separated 200 million years ago when a divergent plate boundary formed between them. What happened in the area between these land masses?


Lava on the Ocean Floor

Lava erupts at both convergent plate boundaries and divergent plate boundaries, as shown in Figure 13. This lava hardens and forms new crust. At an oceanic divergent plate boundary, the newly formed crust is added to the edges of the plates as new ocean crust. As the plates move apart, more lava fills in the space and forms more ocean crust. The seafloor between North America and Europe is made of ocean crust that formed after the continents began to spread apart.

Mountains on the Ocean Floor

The ocean crust made at divergent plate boundaries is not flat. **Mid-ocean ridges** are long, narrow mountains formed by magma at divergent boundaries. The mid-ocean ridge in the Atlantic Ocean begins near the North Pole and continues down the middle of the Atlantic Ocean, nearly all the way to the South Pole. Mid-ocean ridges usually have gentle slopes and are about 2 km high.

Even though explosive volcanic eruptions usually occur near convergent plate boundaries, more lava erupts at divergent plate boundaries. Three-quarters of all lava erupts at mid-ocean ridges. As lava erupts under water, it hardens into flows and unique shapes such as pillow lava, shown in Figure 13.

 **Reading Check** What is a mid-ocean ridge?

Mountains at Convergent Boundaries

Mountains form when Earth's crust folds and crumples. Where do you think this happens? Recall that tectonic plates are rigid pieces of lithosphere. The center of these rigid plates usually does not fold as a result of collisions. Folding and crumpling usually occur at the edges of plates. This is why most mountains form near plate boundaries.

Recall that volcanoes form at convergent plate boundaries where one plate subducts under the other. These volcanoes form volcanic mountain chains along the plate boundaries. The Andes in South America and the Cascade Range in North America formed this way.

When two continents collide at a convergent plate boundary, large mountain ranges form. The tectonic plates are under extreme pressure and fold or crumple upward. The Himalayas, shown in Figure 14, formed as the Indian Plate converged with the Eurasian Plate. The Himalayas are the largest and highest mountain range in the world, and they are still growing!

The Appalachian Mountains in the eastern United States and the Caledonian mountains in Scotland and Scandinavia formed at convergent plate boundaries. However, over millions of years, tectonic motion has moved these mountain chains. Figure 15 shows two maps comparing the locations of these mountain chains on Pangaea and on present-day landmasses.

 **Key Concept Check** How does plate movement form mountains?



Figure 14 Earth's tallest mountains are in the Himalayas. The Himalayas formed at the convergent plate boundary between the Indian Plate and the Eurasian Plate.

Mountains and Plate Movement

 Concepts in Motion Animation

Figure 15 The Appalachian Mountains in North America and the Caledonian mountains in Eurasia formed at the same convergent boundary. Over time, plate motion separated the mountains.

 **Visual Check** What mountain chains once lined up across land masses?

