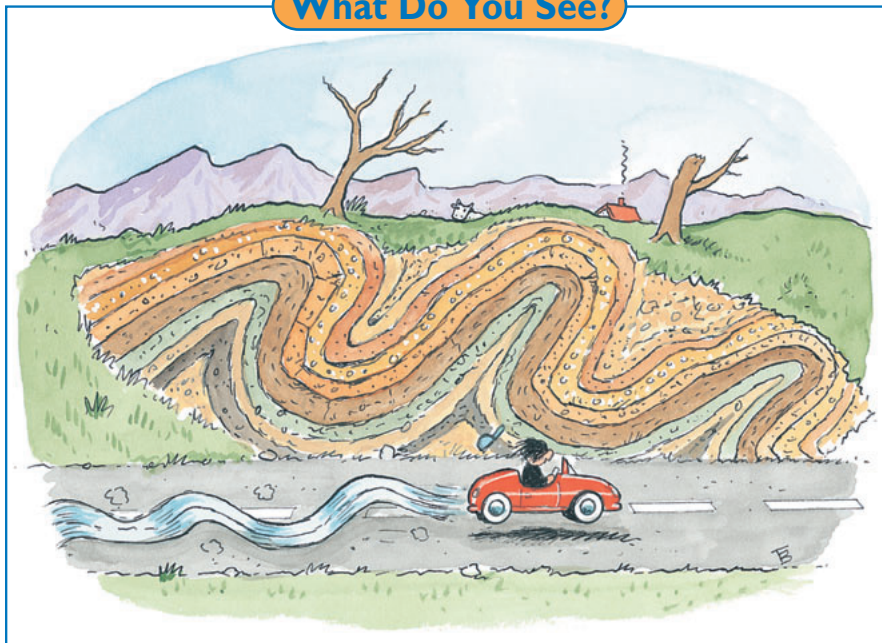




## Section 6

# Structural Geology and Your Community

### What Do You See?



### Learning Outcomes

In this section, you will

- **Describe** the relationship between fault movement and the forces that cause this motion.
- **Understand** that Earth movements can create faults and folds.
- **Understand** that models help scientists understand how things work.

### Think About It

Marble is metamorphosed limestone, a rock that is deposited in nearly horizontal layers. You may have seen marble in buildings, statues, and headstones in cemeteries. It is commonly used for these purposes because it is soft and easy to carve into shapes.

- What would happen if you tried to use a powerful machine to fold a marble bench?
- How are rocks able to fold naturally without first breaking?

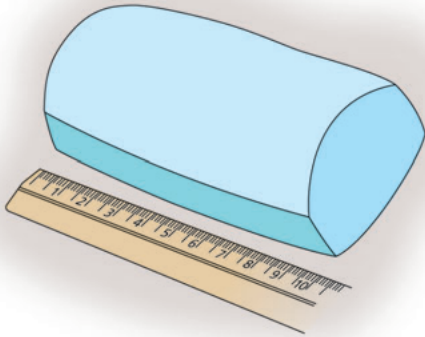
Record your ideas about these questions in your *Geo* log. Be prepared to discuss your responses with your small group and the class.

### Investigate

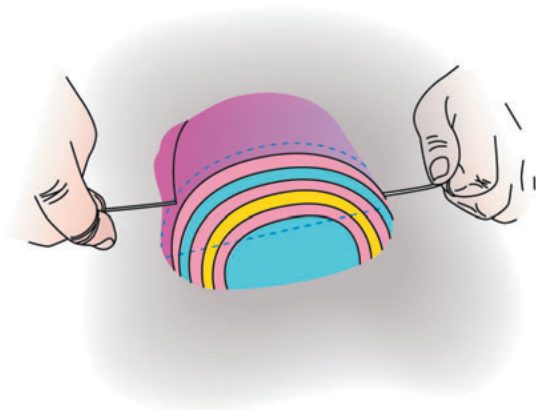
In this *Investigate*, you will observe models of *folds* and *faults* in rock layers. You will then compare these models to what you can see in geologic maps and cross sections.

### Part A: Modeling Folds

1. Mold a large lump of soft modeling clay into the shape shown in the figure below. The block should be about 10 cm long, about 8 cm wide, and have a rounded top. This is your “base block.”



2. Put another lump of clay onto a sheet of wax paper and roll it out with a rolling pin or a wooden dowel into a sheet about 6 mm thick. Drape the sheet over your base block and trim the edges.
3. Repeat *Step 2* with lumps of different colored clay until you have five or six layers. As you place the layers on the block, shape them slightly with your fingers so that they keep almost the same shape as the top of your base block. You now have a block of folded rock layers.
4. Use your hands to stretch a length of dental floss or fishing line tightly, and use it to slice through your folded block. Make two slices: One should be straight down through the block, perpendicular to its long dimension and off to one side, and the other should be horizontal, through the middle of the base block and folds, as shown in the following diagram.



- a) In your log, sketch what the folds in your block look like on the faces of each of the cuts you made. The vertical cut is what real folded rocks look like in a cross-section view, and the horizontal cut is what real folded rocks look like in a map view.

### Part B: Modeling Faults

1. Obtain styrene foam blocks that have been cut into two pieces at an angle, as shown in the photograph below. Use colored pencils or pens to create at least three horizontal layers on the sides of your square.



2. Place the two cut sides of the styrene foam together, face to face. The plane where the two cut surfaces are in contact is a model of a fault plane. Slowly push the two pieces together, so that the upper piece slides upward relative to the lower piece.

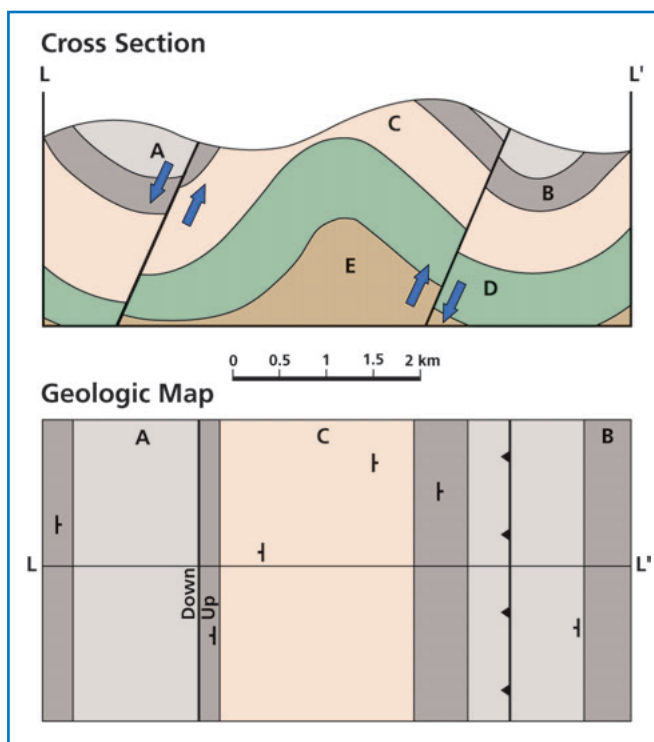


- a) Sketch a side view and a top view of what happens. Use arrows to show the direction of force. Use a different type of arrow to show how the colored layers moved in relation to one another along the fault plane.
3. Start over again with the two pieces of styrene foam face to face. Slowly slide the lower piece upward relative to the upper piece.
  - a) Sketch a side view and a top view of what happens. Again, use arrows to indicate the direction of force and the movement of layers.
  - b) What is the difference in the way the styrene foam blocks moved in these two trials?
4. Return the styrene foam to the original position. Move the pieces so that they slide sideways past each other.
  - a) Sketch a picture of the pieces. Use arrows to indicate the direction of force and the movement of layers.

### Part C: Interpreting Structure Using Geologic Maps and Cross Sections

1. Geologic maps have special symbols to indicate the locations of faults and folds. Many maps also show one or more cross sections. A cross section shows how the rocks are deformed and makes it easier to infer what forces caused the deformation. Use a copy of the following geologic map and cross section to complete the following:
  - a) Color the cross section and the map. Use a different color for each of the five rock layers A through E.

- b) Sediments are almost always deposited in nearly flat, horizontal layers. What evidence suggests that the rock layers in this region were deformed by forces within Earth?
- c) Were the faults produced by *compression* (pushing forces), *tension* (pulling forces), or *shear* (sideways forces) in the rock layers? Explain your answer.
- d) Are the folds in the rock layers consistent with your answer above? Explain your answer.
- e) Compare what you see in the cross section and the map to your models of folds and faults from *Parts A and B*.



## Digging Deeper

### FORCES IN EARTH'S CRUST

#### Types of Forces

In the *Investigate*, you observed models of folds and faults in rock layers using clay and styrene foam. You then compared these models to what you could see in geologic maps and cross sections. This *Digging Deeper* will help you to understand how rock layers form and then can become folded or faulted.

Earlier in this chapter, you read that sedimentary rocks form from sediments that are originally laid down in almost flat, horizontal layers. In many places on Earth, however, sedimentary and other kinds of rocks are not found in a horizontal position. Instead, they are tilted at some angle to the horizontal. Sometimes they are tilted so much that the layers are vertical. The tilting of the layers is a sign that they have been deformed by forces acting within Earth. The forces can cause the rocks to become folded. **Folds** are usually formed when rocks are squeezed together by compressive forces. The forces can cause the rocks to fracture and then to slip along the fracture surfaces. A fracture surface along which rocks slip is called a fault. Forces within Earth that cause folding and faulting are created by the movement of Earth's lithospheric plates. The plates move very slowly (2 to 20 cm/yr). However, over hundreds to thousands of years, great forces build up in Earth's crust. These forces are transmitted for long distances through the crust. As a result, folding and faulting can happen not only near plate boundaries but also in the interiors of the continents, far from plate boundaries.

Three different kinds of forces can cause rocks to deform. They are **tension forces**, **compression forces**, and **shear forces**. As you saw in the *Investigate*, different types of forces have different effects on rock layers. Suppose you are holding a solid, rectangular block between your hands. When you try to pull the block apart at its ends, you are exerting a tension force. When you push the ends of the block together, you are exerting a compression force. When you hold two opposite edges of the block and try to move them in opposite directions, you are exerting a shear force. In all three cases, if the force you exert is greater than the strength of the solid material, it deforms. It will deform either by fracturing or just changing its shape without actually breaking. The forces that are created in Earth's crust by the movement of lithospheric plates are often great enough to deform the rocks.

#### Folding and Faulting

What determines whether a rock is faulted or folded? It is partly a matter of temperature. At lower temperatures, as in the upper parts of Earth's crust, rocks are brittle. They tend to deform by fracturing. In the lower parts of Earth's crust, the temperature of rocks is relatively high.

#### Geo Words

**fold:** a bend in a planar feature in rocks. A fold is usually a result of deformation.

**tension force:** a force that tends to pull material apart.

**compression force:** a force that tends to push material together.

**shear force:** a force that tends to make two masses of material slide past each other.







**Figure 1** Intense heat and pressure folded these previously horizontal sedimentary layers.

When forces are exerted on rocks at high temperatures, the rocks tend to deform by changing their shape continuously rather than by faulting. Folding is an example of how rocks can change their shape continuously without breaking. This is shown in *Figure 1*. Whether a rock is folded or faulted is also a matter of time. If forces build up very fast, rocks are more likely to fracture. However, if forces build up very slowly, the rocks are more likely to change their shape without breaking.

## Faults

A fault can be formed by tension forces. These forces cause the rocks of the crust to be pulled apart. In that case, the body of rock above the fault plane slides down relative to the body of rock below the fault plane. (See *Figure 2a*.) Faults of this kind are called **normal faults**. A fault can also be formed by compression forces. These forces cause the rocks of the crust to be pushed together. In that case, the body of rock above the fault plane slides upward relative to the body of rock below the fault plane. (See *Figure 2b*.) Faults of this kind are called **reverse faults**. When the fault plane is nearly horizontal, reverse faults are called **thrust faults** instead. When a fault is formed by horizontal shear forces, the bodies of rock on either side of the fault plane slide past each other horizontally. (See *Figure 2c*.) Faults of this kind are called **strike-slip faults**.

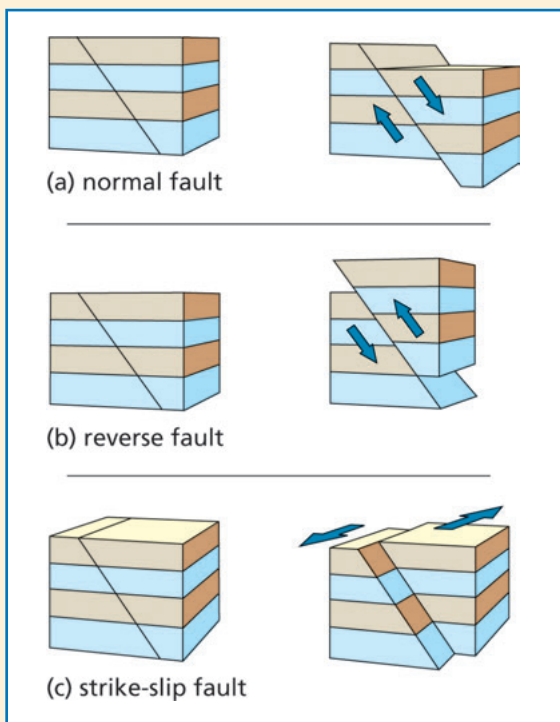
### Geo Words

**normal fault:** a fault formed by tension forces that cause the body of rock above the fault plane to slide down relative to the body of rock below the fault plane.

**reverse fault:** a fault formed by compression forces that cause the body of the rock above the fault plane to slide upward relative to the body of rock below the fault plane.

**thrust fault:** a reverse fault in which the fault plane is nearly horizontal.

**strike-slip fault:** a fault formed by horizontal shear forces that cause the bodies of rock on either side of the fault plane to slide past each other horizontally.



**Figure 2** The three major types of faults. When a reverse fault occurs at an angle of less than  $45^\circ$ , it is called a thrust fault.

Movement on faults usually occurs suddenly after a long time without movement. The forces that cause the faulting build up very slowly. When they become greater than the strength of the rock, the fault moves. This relaxes the forces, which then slowly build up again. Major faults typically move only every few centuries. Most earthquakes are caused by sudden movement on faults.

### Folds

Folds are especially common when the rock is layered, like sedimentary rock, and the layers differ in their stiffness (resistance to being bent). Here is a “thought experiment” to show the effect of layering. Make a square block of soft modeling clay and squeeze it together from opposite sides. It becomes compressed, but it does not form folds. Now make a block that consists of many thin layers of clay separated by index cards. Squeeze the block from opposite sides, in a direction parallel to the index cards. The block then deforms by folding.

Folds in Earth’s crust are usually arranged horizontally. The parts of the folds that are concave upward are called **synclines** (Figure 4a). The parts of the folds that are convex upward are called **anticlines** (Figure 4b). Folds in rocks can be as small as centimeters or as large as many kilometers.



**Figure 3** What kind of fault is shown in this photograph?

### Geo Words

**syncline:** part of a fold that is concave upward.

**anticline:** part of a fold that is convex upward.



**Figure 4a** Sideling Hill in Maryland is an example of a syncline.



**Figure 4b** An anticline in Wyoming.





### Checking Up

1. Describe tension, compression, and shear forces in your own words. You may wish to use a diagram.
2. What factors determine whether a rock will fault or fold?
3. Why do scientists work with models to understand folding and faulting?

### Using Models to Investigate Geologic Structures

Geologic processes, such as folding and faulting of rocks, work over very long time spans. The folding of rocks cannot be observed in nature as it happens. Models help scientists to understand the deformation of rocks. Geologists have used layers of colored wax and a special “squeeze box” to investigate the folding process. The box had a glass wall for viewing the wax from the side. One side of the box moved along threaded rods, creating a force on the wax as the walls closed in on one another. Wax was poured into the box one layer at a time. A knob on one end of the box allowed the wall of the box to be moved horizontally. This movement squeezed the wax from the ends. The model allowed scientists to vary the rate at which the force was applied and the thicknesses of the various layers. The model helped them to create folds that they saw in nature. From this, they were able to make interpretations about the forces that created these folds.

### Think About It Again

At the beginning of this section, you were asked the following:

- What would happen if you tried to use a powerful machine to fold a marble bench?
- How are rocks able to fold naturally without first breaking?

Record your ideas about these questions now. In your answer, include the relationship between forces and fault movements.

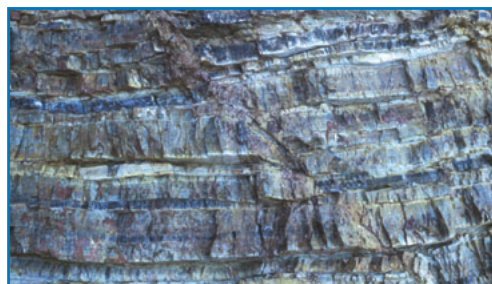
### Reflecting on the Section and the Challenge

Think about what you did in the *Investigate* that you could adapt for your museum exhibit. You first observed a model that showed the way that forces on rocks can cause the rocks to bend. You also observed a model of how the forces on the rocks, if large enough, can cause the rock to fold or fracture. As you observed, forces can sometimes move broken pieces up or down. You will need to help your museum visitors understand that changes within Earth’s crust can cause folds and fractures, an important part of the geologic history of your community and region.



## Understanding and Applying

1. Look at the photograph of faulted rock layers in Pennsylvania.
  - a) Do the rocks appear to have been pulled apart, pushed together, or slid past each other to form this structure?
  - b) What type of fault is this?
2. Look at the photograph of a fault found in California.
  - a) Were the rocks pulled apart, pushed together, or slid past each other to form this structure?
  - b) What type of fault is this?
3. Examine your state geologic map and geologic cross sections.
  - a) How many faults do you see near your community?
  - b) What types of faults do you see?
  - c) How many folds do you see near your community?
  - d) What types of plate motion does this suggest?



A rock exposure in Pennsylvania.



A roadside fault in California.

### 4. *Preparing for the Chapter Challenge*

Help your exhibit visitors to interpret the geologic history of your local area and region in terms of motion in Earth's crust. To do this, you will need to use your knowledge of how crustal movements result in faults and folds. If your area has not undergone a great deal of deformation, try to explain why you think your region is so stable. Think about the oldest rocks in your area and use words, pictures, or videos in your exhibit to describe any deformation that might have occurred.

## Inquiring Further

### 1. Geologic structures in a national park

Look at a geologic map and cross section of the Grand Tetons in Wyoming. Research the types of structures, folds, and faults in this area. Interpret the geologic history of the area.

### 2. Careers in structural geology

Visit the *EarthComm* Web site at <http://www.agiweb.org/education/earthcomm2/> to find a structural geologist who lives and works in your state or region. Introduce yourself through a letter or e-mail message. Briefly describe the work that you are doing in your *EarthComm* classroom. Ask one or two questions that will help you learn about careers in structural geology. Examples include:

- What makes structural geology so interesting to you?
- What made you decide to become a structural geologist?
- What do you think is the most challenging aspect of structural geology?
- What do you enjoy most about your work?