Section 1

Forces in Earth's Crust

Reading Preview

Key Concepts

- How does stress in the crust change Earth's surface?
- Where are faults usually found, and why do they form?
- What land features result from the forces of plate movement?

Key Terms

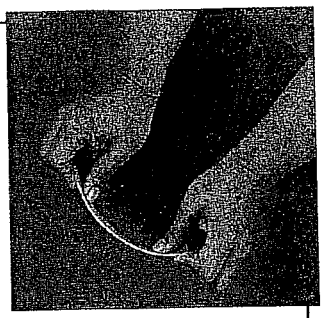
- stress • tension
- compression • shearing
- normal fault • hanging wall
- footwall • reverse fault
- strike-slip fault • anticline
- syncline • plateau

Target Reading Skill

Building Vocabulary

A definition states the meaning of a word or phrase. As you read, write a definition of each Key Term in your own words.

Lab zone Discover Activity



How Does Stress Affect Earth's Crust?

1. Put on your goggles.
2. Holding a popsicle stick at both ends, slowly bend it into an arch.
3. Release the pressure on the popsicle stick and observe what happens.
4. Repeat Steps 1 and 2. This time, however, keep bending the ends of the popsicle stick toward each other. What happens to the wood?

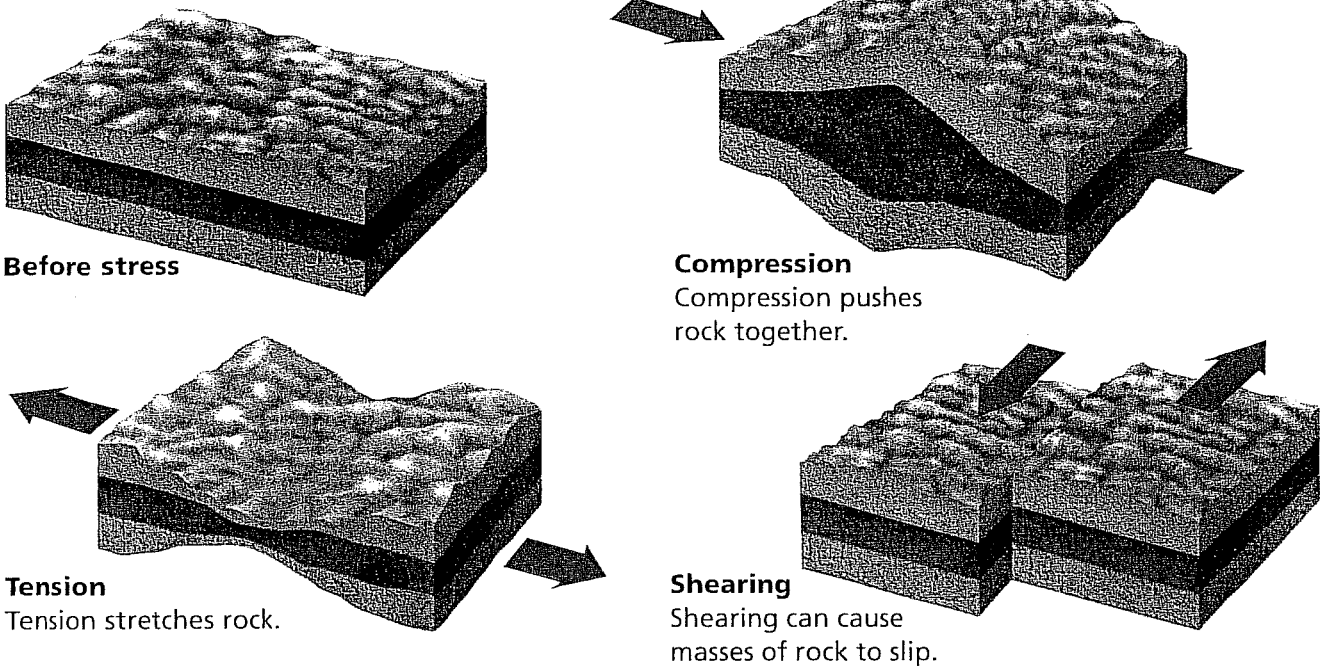
Think It Over

Predicting Think of the popsicle stick as a model for part of Earth's crust. What do you think might eventually happen as the forces of plate movement bend the crust?

The movement of Earth's plates creates enormous forces that squeeze or pull the rock in the crust as if it were a candy bar. These forces are examples of **stress,** a force that acts on rock to change its shape or volume. (A rock's volume is the amount of space the rock takes up.) Because stress is a force, it adds energy to the rock. The energy is stored in the rock until the rock changes shape or breaks.

If you try to break a caramel candy bar in two, it may only bend and stretch at first. Like a candy bar, many types of rock can bend or fold. But beyond a certain limit, even these rocks will break.

FIGURE 1
Effects of Stress
Powerful forces in Earth's crust caused the ground beneath this athletic field in Taiwan to change its shape.



Types of Stress

Three different kinds of stress can occur in the crust—tension, compression, and shearing. **Tension, compression, and shearing work over millions of years to change the shape and volume of rock.** These forces cause some rocks to become brittle and snap. Other rocks bend slowly, like road tar softened by the sun. Figure 2 shows how stress affects the crust.

Most changes in the crust occur so slowly that they cannot be observed directly. But if you could speed up time so a billion years passed by in minutes, you could see the crust bend, stretch, break, tilt, fold, and slide. The slow shift of Earth's plates causes these changes.

Tension The stress force called **tension** pulls on the crust, stretching rock so that it becomes thinner in the middle. The effect of tension on rock is somewhat like pulling apart a piece of warm bubble gum. Tension occurs where two plates are moving apart.

Compression The stress force called **compression** squeezes rock until it folds or breaks. One plate pushing against another can compress rock like a giant trash compactor.

Shearing Stress that pushes a mass of rock in two opposite directions is called **shearing.** Shearing can cause rock to break and slip apart or to change its shape.

Reading Checkpoint **How does shearing affect rock in Earth's crust?**

FIGURE 2
Stress in Earth's Crust
Stress forces push, pull, or twist the rocks in Earth's crust.
Relating Cause and Effect *Which type of stress tends to shorten part of the crust?*

Kinds of Faults

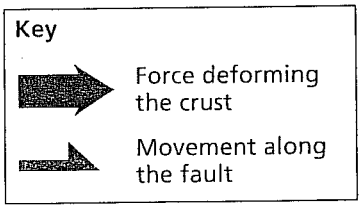
When enough stress builds up in rock, the rock breaks, creating a fault. Recall that a fault is a break in the rock of the crust where rock surfaces slip past each other. The rocks on both sides of a fault can move up or down or sideways. **Most faults occur along plate boundaries, where the forces of plate motion push or pull the crust so much that the crust breaks. There are three main types of faults: normal faults, reverse faults, and strike-slip faults.**

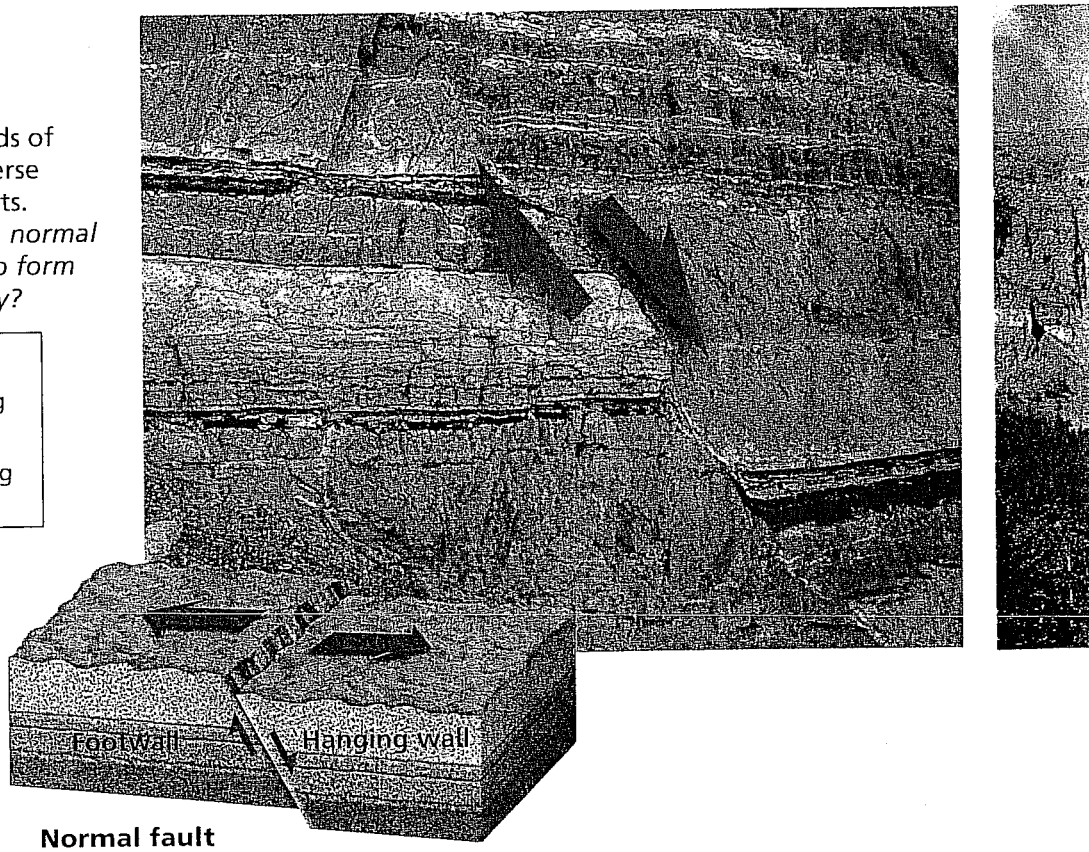
Normal Faults Tension in Earth's crust pulls rock apart, causing **normal faults.** In a normal fault, the fault is at an angle, so one block of rock lies above the fault while the other block lies below the fault. The block of rock that lies above is called the **hanging wall.** The rock that lies below is called the **footwall.** Look at Figure 3 to see how the hanging wall lies above the footwall. When movement occurs along a normal fault, the hanging wall slips downward. Normal faults occur where plates diverge, or pull apart. For example, normal faults are found along the Rio Grande rift valley in New Mexico, where two pieces of Earth's crust are under tension.

FIGURE 3

Kinds of Faults

There are three main kinds of faults: normal faults, reverse faults, and strike-slip faults.
Inferring *Which half of a normal fault would you expect to form the floor of a valley? Why?*



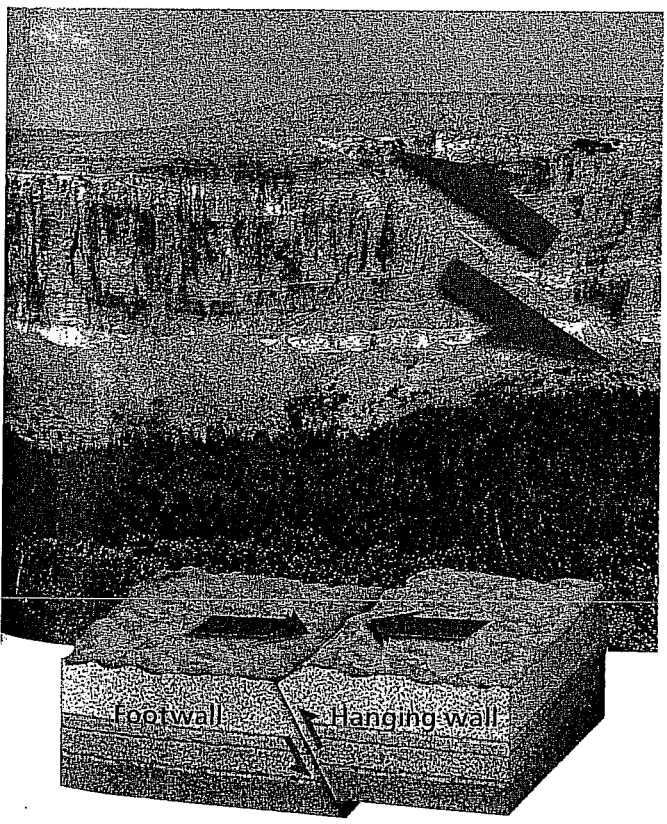


Normal fault
In a normal fault, the hanging wall slips down relative to the footwall.

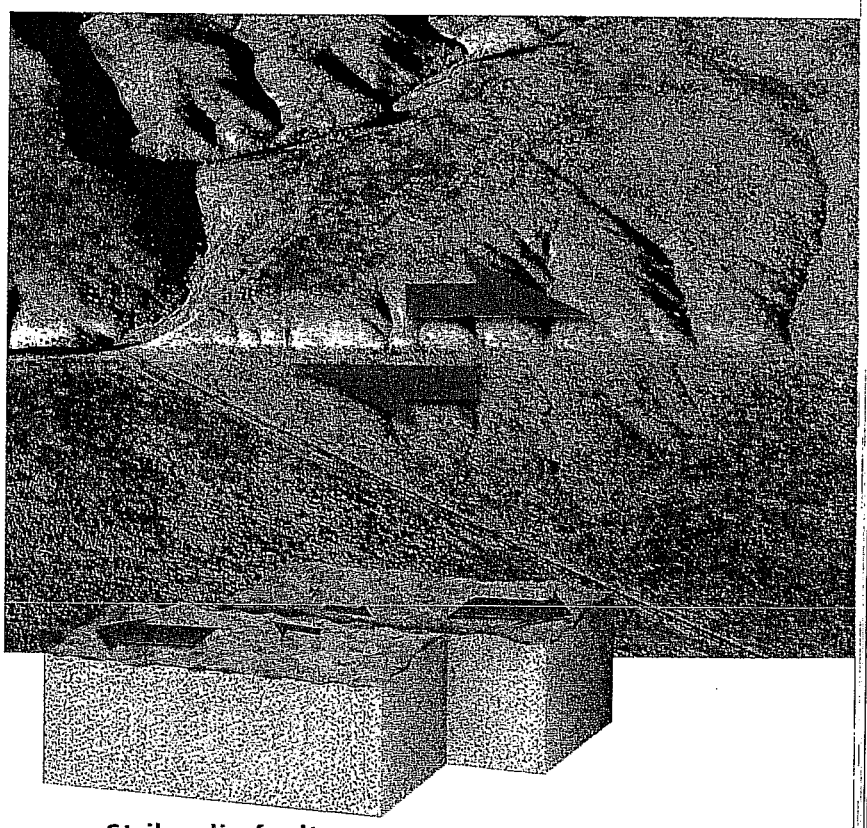
Reverse Faults In places where the rock of the crust is pushed together, compression causes reverse faults to form. A **reverse fault** has the same structure as a normal fault, but the blocks move in the opposite direction. Look at Figure 3 to see how the rocks along a reverse fault move. As in a normal fault, one side of a reverse fault lies at an angle above the other side. The rock forming the hanging wall of a reverse fault slides up and over the footwall. Movement along reverse faults produced part of the northern Rocky Mountains in the western United States and Canada.

Strike-Slip Faults In places where plates move past each other, shearing creates strike-slip faults. In a **strike-slip fault,** the rocks on either side of the fault slip past each other sideways, with little up or down motion. A strike-slip fault that forms the boundary between two plates is called a transform boundary. The San Andreas fault in California is an example of a strike-slip fault that is a transform boundary.

Reading Checkpoint **What is the difference between a hanging wall and a footwall?**



Reverse fault
In a reverse fault, the hanging wall moves up relative to the footwall.



Strike-slip fault
Rocks on either side of a strike-slip fault slip past each other.

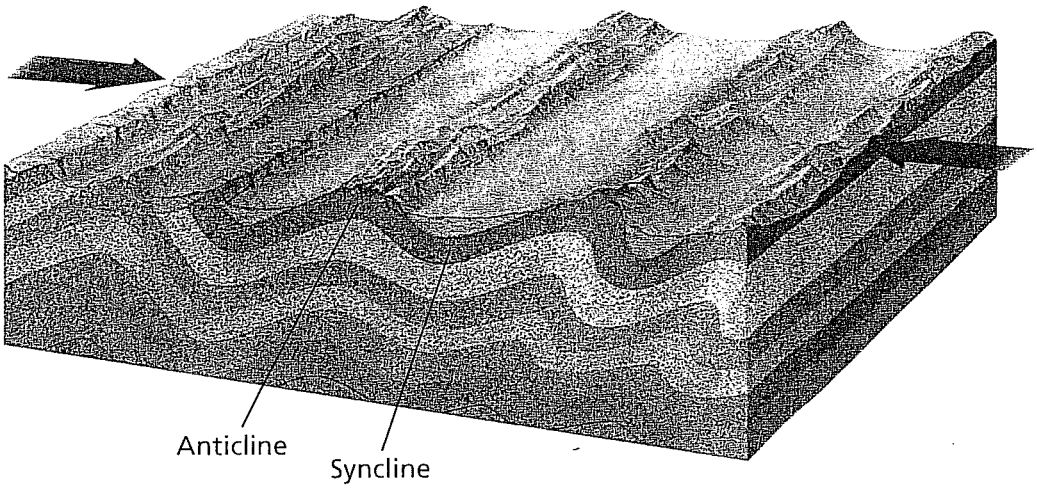


FIGURE 4
Effects of Folding Compression and folding of the crust produce anticlines, which arch upward, and synclines, which dip downward. Over millions of years, folding can push up high mountain ranges.
Predicting *If the folding in the diagram continued, what kind of fault might form?*

Changing Earth's Surface

The forces produced by the movement of Earth's plates can fold, stretch, and uplift the crust. **Over millions of years, the forces of plate movement can change a flat plain into landforms such as anticlines and synclines, folded mountains, fault-block mountains, and plateaus.**

Folding Earth's Crust Sometimes plate movement causes the crust to fold. Have you ever skidded on a rug that wrinkled up as your feet pushed it across the floor? Much as the rug wrinkles, rock stressed by compression may bend without breaking. Folds are bends in rock that form when compression shortens and thickens part of Earth's crust. A fold can be only a few centimeters across or hundreds of kilometers wide. You can often see small folds in the rock exposed where a highway has been cut through a hillside.

Geologists use the terms anticline and syncline to describe upward and downward folds in rock. A fold in rock that bends upward into an arch is an **anticline,** shown in Figure 4. A fold in rock that bends downward to form a valley is a **syncline.** Anticlines and synclines are found in many places where compression forces have folded the crust. The central Appalachian Mountains in Pennsylvania are folded mountains made up of parallel ridges (anticlines) and valleys (synclines).

The collision of two plates can cause compression and folding of the crust over a wide area. Folding produced some of the world's largest mountain ranges. The Himalayas in Asia and the Alps in Europe formed when pieces of the crust folded during the collision of two plates.

Lab zone Try This Activity

Modeling Stress

You can model the stresses that create faults.

1. Knead a piece of plastic putty until it is soft.
2. Push the ends of the putty toward the middle.
3. Pull the ends apart.
4. Push half of the putty one way and the other half in the opposite direction.

Classifying Which step in this activity models the type of stress that would produce anticlines and synclines?

Stretching Earth's Crust When two normal faults cut through a block of rock, a fault-block mountain forms. You can see a diagram of this process in Figure 5. How does this process begin? Where two plates move away from each other, tension forces create many normal faults. When two of these normal faults form parallel to each other, a block of rock is left lying between them. As the hanging wall of each normal fault slips downward, the block in between moves upward, forming a fault-block mountain.

If you traveled by car from Salt Lake City to Los Angeles, you would cross the Great Basin. This region contains many ranges of fault-block mountains separated by broad valleys, or basins.

Reading Checkpoint **What type of plate movement causes fault-block mountains to form?**

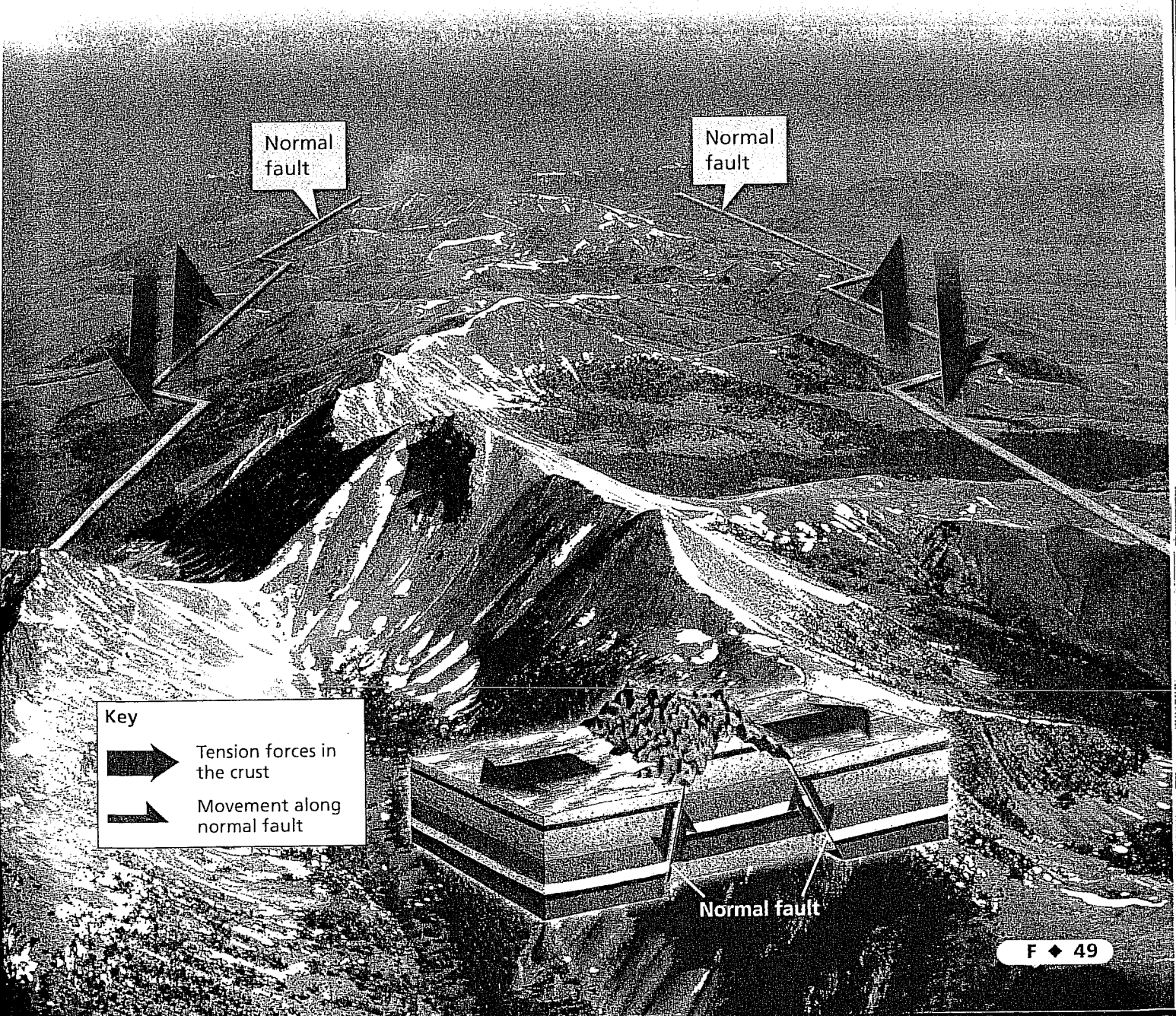


FIGURE 5
Fault-Block Mountains
As tension forces pull the crust apart, two parallel normal faults can form a range of fault-block mountains, like the Beaverhead Range in Idaho.

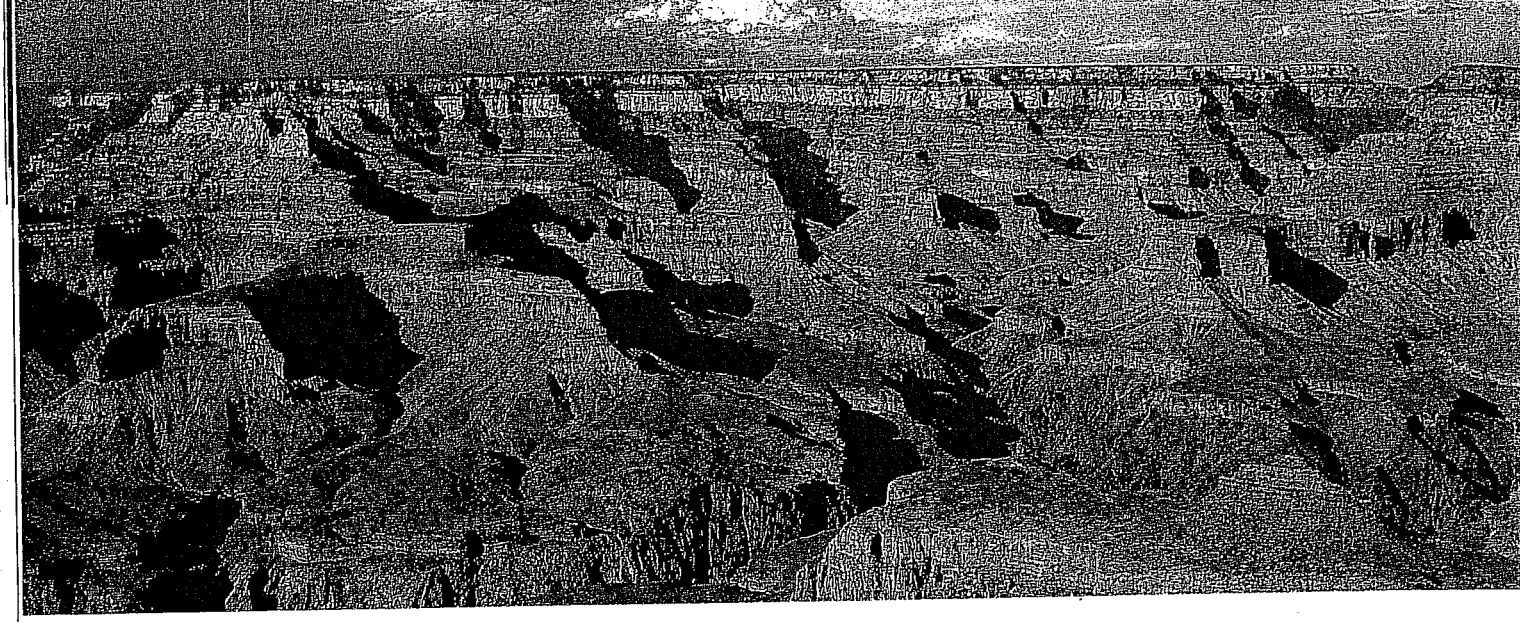


FIGURE 6
The Kaibab Plateau
The flat land on the horizon is the Kaibab Plateau, which forms the North Rim of the Grand Canyon in Arizona. The Kaibab Plateau is part of the Colorado Plateau.

Uplifting Earth's Crust The forces that raise mountains can also uplift, or raise, plateaus. A **plateau** is a large area of flat land elevated high above sea level. Some plateaus form when forces in Earth's crust push up a large, flat block of rock. Like a fancy sandwich, a plateau consists of many different flat layers, and is wider than it is tall.

Forces deforming the crust uplifted the Colorado Plateau in the "Four Corners" region of Arizona, Utah, Colorado, and New Mexico. Much of the Colorado Plateau lies more than 1,500 meters above sea level. Figure 6 shows one part of that plateau in northern Arizona.

Section 1 Assessment

Target Reading Skill **Building Vocabulary** Refer to your definitions of the Key Terms to help you answer the following questions.

Reviewing Key Concepts

1. a. **Reviewing** What are the three main types of stress in rock?
   b. **Relating Cause and Effect** How does tension change the shape of Earth's crust?
   c. **Comparing and Contrasting** Compare the way that compression affects the crust to the way that tension affects the crust.
2. a. **Describing** What is a fault?
   b. **Explaining** Why do faults often occur along plate boundaries?
   c. **Relating Cause and Effect** What type of fault is formed when plates diverge, or pull apart? What type of fault is formed when plates are pushed together?
3. a. **Listing** Name five kinds of landforms caused by plate movement.
   b. **Relating Cause and Effect** What are three landforms produced by compression in the crust? What landform is produced by tension?

Lab zone At-Home Activity

Modeling Faults To model Earth's crust, roll modeling clay into layers and then press the layers together to form a rectangular block. Use a plastic knife to slice through the block at an angle, forming a fault. Explain which parts of your model represent the land surface, the hanging wall, and the footwall. Then show the three ways in which the sides of the fault can move.