Earth Dynamics

Forces That Shape Earth

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	1. Forces created by plate motion are small and do not deform or break rocks.	
	2. Plate motion causes only horizontal motion of continents.	

Key Concepts

- How do continents move?
- What forces can change rocks?
- How does plate motion affect the rock cycle?

Read to Learn

Plate Motion

How far is your school from the nearest large mountain? If you live in the west or along the east coast of the United States, you are probably close to mountains. However, the central region of the United States is flat. Mountains exist in some regions of the United States but not in others. Do you know why?

Mountain Building Plate tectonics produce mountain ranges. The theory of plate tectonics states that Earth's surface is broken into rigid plates. These plates move horizontally on Earth's fluid upper mantle. Mountains and valleys form where plates collide, move away from each other, or slide past each other.

Mountain Erosion Not all mountain ranges are the same. The Rocky Mountains in the west are high and have sharp peaks. They formed 50 to 100 million years ago. The Appalachian Mountains in the east are low and gently rounded. They formed hundreds of millions of years ago.

Mountains do not last forever. Weathering and erosion gradually wear them down. The Appalachian Mountains are lower and smoother than the Rockies because they are older.

Mark the Text

Building Vocabulary As you read, circle all the words you do not understand. Highlight the part of the text that helps you understand these words. Review the marked words and their definitions after you finish reading the lesson.

Reading Check

1. Contrast How are the Rocky Mountains different from the Appalachian Mountains?

Vertical Motion

Massive pieces of Earth can rise vertically and form mountainous regions. To understand how this happens, you need to understand the forces that produce vertical motion.

Balance in the Mantle

Think of an iceberg floating in water. The iceberg floats with its top above the water. However, most of the iceberg is under the surface of the water.

An iceberg floats this way because ice is less dense than water. The mass of the ice equals the mass of the water it displaces, or pushes out of the way. You can compare an iceberg to a continent.

Isostasy Continents rise above the seafloor because continental crust is made of rocks that are less dense than Earth's mantle. Continental crust displaces some of the mantle below it until an equilibrium, or balance, is reached. **Isostasy** (i SAHS tuh see) *is the equilibrium between continental crust and the denser mantle below it*. A continent floats on top of the mantle because the mass of the continent equals the mass of the mantle it displaces. Mountains displace mantle just as continents do, but on a smaller scale.

Maintaining a Balance Plate tectonics and erosion change continental crust over time. If a part of the continental crust becomes thicker, the crust sinks deeper into the mantle, as shown in the first image in the figure on the next page. But the continental crust also rises higher until a balance is reached. This is why mountains are taller than the continental crust around them. Although a mountain is massive, it is still less dense than the mantle. The mountain "floats." Below Earth's surface, the mountain extends deep into the mantle. Above Earth's surface, the mountain rises above the surrounding continental crust.

Over time, erosion and weathering remove the top of the mountain. As the mountain erodes, the continental crust rises, as shown in the last two images of the figure on the next page. The continental crust rises until it reaches a balance with the mantle. Continents maintain isostasy as they move up or down until the mass of the continent equals the mass of the mantle it displaces.

Think it Over

2. Sketch an iceberg in the space below. Include the surface of the water in your sketch.

Reading Check

3. Define What is isostasy?

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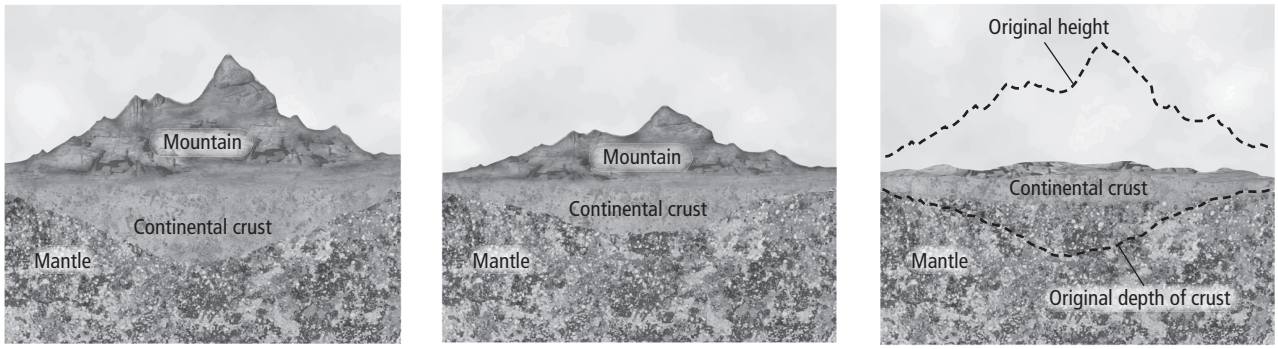
_____

Think it Over

4. Predict The top of the Appalachian Mountain range is eroding. How is the continental crust moving in response to the erosion?

_____

Maintaining Balance



Subsidence and Uplift

Glaciers more than 1 km thick covered much of North America 20,000 years ago. The weight of the ice pushed the crust downward into the mantle. *The downward vertical motion of Earth's surface is called* **subsidence.**

As the ice melted and the water ran off, the isostatic balance was again upset. The crust began moving upward. *The upward vertical motion of Earth's surface is called* **uplift.** In the center of Hudson Bay in Canada, the continental crust is still rising 1 cm each year as it moves toward isostatic balance.

Horizontal Motion

Find a small rock and squeeze it. You've just applied force to the rock. Did its shape change? Did it break? Probably not.

Horizontal motion at plate boundaries applies much greater forces to rocks than you can apply. Forces at plate boundaries are strong enough to break rocks or change their shape. The same forces also can form mountains.

Types of Stress

Stress is the force acting on a surface. There are three types of stress: compression, tension, and shear.

Squeezing stress is **compression.** *Stress that pulls something apart is* **tension.** *Parallel forces acting in opposite directions are* **shear.** Compression, tension, and shear stresses can change the shape of rocks as plates move horizontally.

Visual Check

5. Locate Use a highlighter to mark the boundary between the mantle and the continental crust in each part of the figure.

Key Concept Check

6. Analyze What can cause Earth's surface to move up or down?

FOLDABLES®

Make a three-tab book to describe the forces that shape Earth.

Types of Strain

Rocks can change when stress acts on them. *A change in the shape of rock caused by stress is called* **strain.** There are two main types of strain: elastic strain and plastic strain.

Elastic Strain When stresses are small or rocks are very strong, elastic strain occurs. Elastic strain does not deform, or permanently change, rocks. When the stress is gone, rocks return to their original shapes.

Reading Check

7. Distinguish Which type of strain permanently changes rocks?

_____

Plastic Strain Deformation (dee for MAY shun), a permanent change in shape, is caused by plastic strain. Even when the stress is removed, the rocks do not go back to their original shapes. Plastic strain occurs when rocks are weak or hot.

Deformation in the Crust

In the hotter lower crust and upper mantle, rocks tend to deform plastically like putty. As illustrated in the figure below, compression thickens and folds layers of rock. Tension stretches and thins layers of rock.

Key Concept Check

8. Specify What can cause rocks to thicken or fold?

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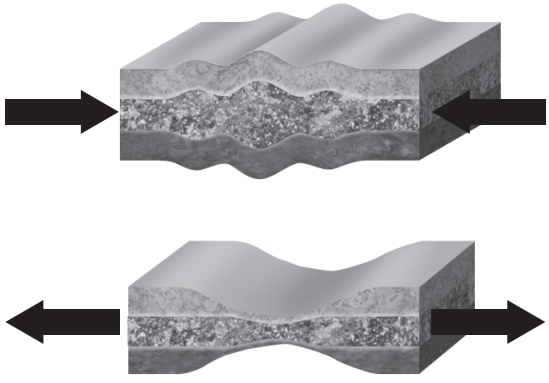
In the colder, upper part of the crust, rocks can break before they deform plastically. When strain breaks rocks rather than just changing their shape, it is called failure. When rocks fail, fractures or faults form.

Compression and Tension



Visual Check

9. Identify Which of these two illustrations shows tension?

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Plate Tectonics and the Rock Cycle

Although rocks seem to stay the same, they are moving around—usually very slowly. Rocks never stop moving through the rock cycle. The theory of plate tectonics combined with uplift and subsidence explains why Earth has a rock cycle.

Horizontal and Vertical Motion The forces that cause plate tectonics produce horizontal motion. Isostasy results in vertical motion within continents. Together, plate motion, uplift, and subsidence keep rocks moving through the rock cycle.

The Rock Cycle Uplift brings metamorphic and igneous rocks from deep in the crust up to the surface. At the surface, erosion breaks down rocks into sediment. Sediment gets buried by still more sediment. Buried sediment becomes sedimentary rocks.

Pressure and temperature increase as sedimentary rocks are buried. Eventually, sedimentary rocks become metamorphic rocks. Subduction takes all types of rocks deep into Earth. There they can melt and become igneous or metamorphic rocks.

Key Concept Check

10. Explain How does plate motion affect the rock cycle?

Mini Glossary

compression: squeezing stress

isostasy (i SAHS tuh see): the equilibrium between continental crust and the denser mantle below it

shear: parallel forces acting in opposite directions

strain: a change in the shape of rock caused by stress

subsidence: the downward vertical motion of Earth's surface

tension: stress that pulls something apart

uplift: the upward vertical motion of Earth's surface

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains how compression differs from tension.

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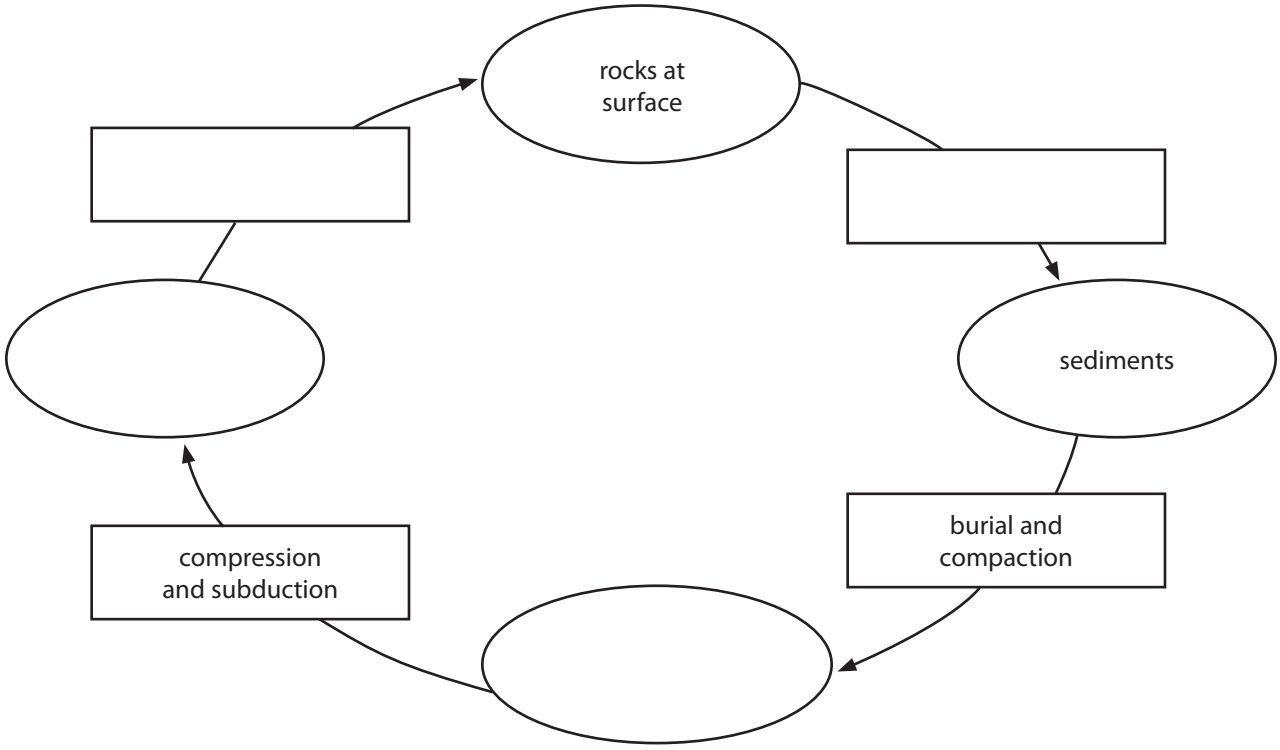
_____

2. The diagram below illustrates one path in Earth's rock cycle. Use these terms to complete the diagram: metamorphic rock, erosion, sedimentary rock, uplift.



What do you think NOW?

Reread the statements at the beginning of the lesson. Fill in the After column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

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END OF LESSON