

Earth's Structures



Earth Structures

This delta may look different than it did 10 years ago.

What Do You Think?

Earth is continuously changing. How did the rock cycle change the delta over time? As you explore this unit, gather evidence to help you state and support a claim.

Earth's Structures

LESSON 1
Minerals 90
 SC.7.E.6.2

FOCUS ON FLORIDA 104
 SC.7.E.6.2

LESSON 2
The Rock Cycle 106
 SC.7.E.6.2

ENGINEERING & TECHNOLOGY
Analyzing the Life Cycles of Aluminum and Glass 118
 SC.7.N.1.1

LESSON 3
Earth's Layers 122
 SC.7.E.6.1, SC.7.E.6.7

LESSON 4
Plate Tectonics 130
 SC.7.E.6.1, SC.7.E.6.2, SC.7.E.6.5, SC.7.E.6.7

PEOPLE IN SCIENCE 144
 SC.7.N.1.5

LESSON 5
Mountain Building 146
 SC.7.N.1.1, SC.7.E.6.5, SC.7.E.6.7

LESSON 6
Earthquakes 156
 SC.7.N.1.1, SC.7.E.6.5, SC.7.E.6.7

ENGINEERING & TECHNOLOGY
Building a Seismometer 166
 SC.7.N.1.3

LESSON 7
Volcanoes 170
 SC.7.E.6.5, SC.7.E.6.7

 **Benchmark Review** 183

CITIZEN SCIENCE

Stable Structures

The building on the right, located in San Francisco, was engineered to protect it from earthquakes.

1 Think About It

People in different parts of the United States—and all over the world—need to make buildings earthquake-proof. Where would it be of most importance to have earthquake-proof buildings?

The taller the building, the more difficult it is to make it safe during an earthquake. Why do you think this is?

Some materials survive the shaking from an earthquake, while others crumble or crack. What materials might withstand an earthquake? Why?

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2 Ask A Question

How earthquake-safe are the buildings in your community?

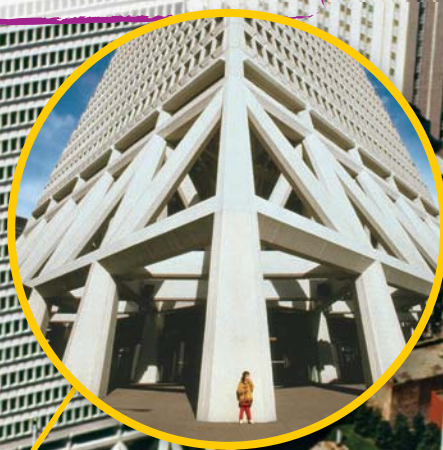
With a partner, evaluate the earthquake safety of a local building. You will need to gather information about the building materials used in the construction of your chosen building.

3 Apply Your Knowledge

A List the factors that you will need to evaluate.

B Create a list of improvements that you would make to the building to make it earthquake-proof.

The diagonal trusses of this building are designed to withstand earthquakes.



Take It Home!

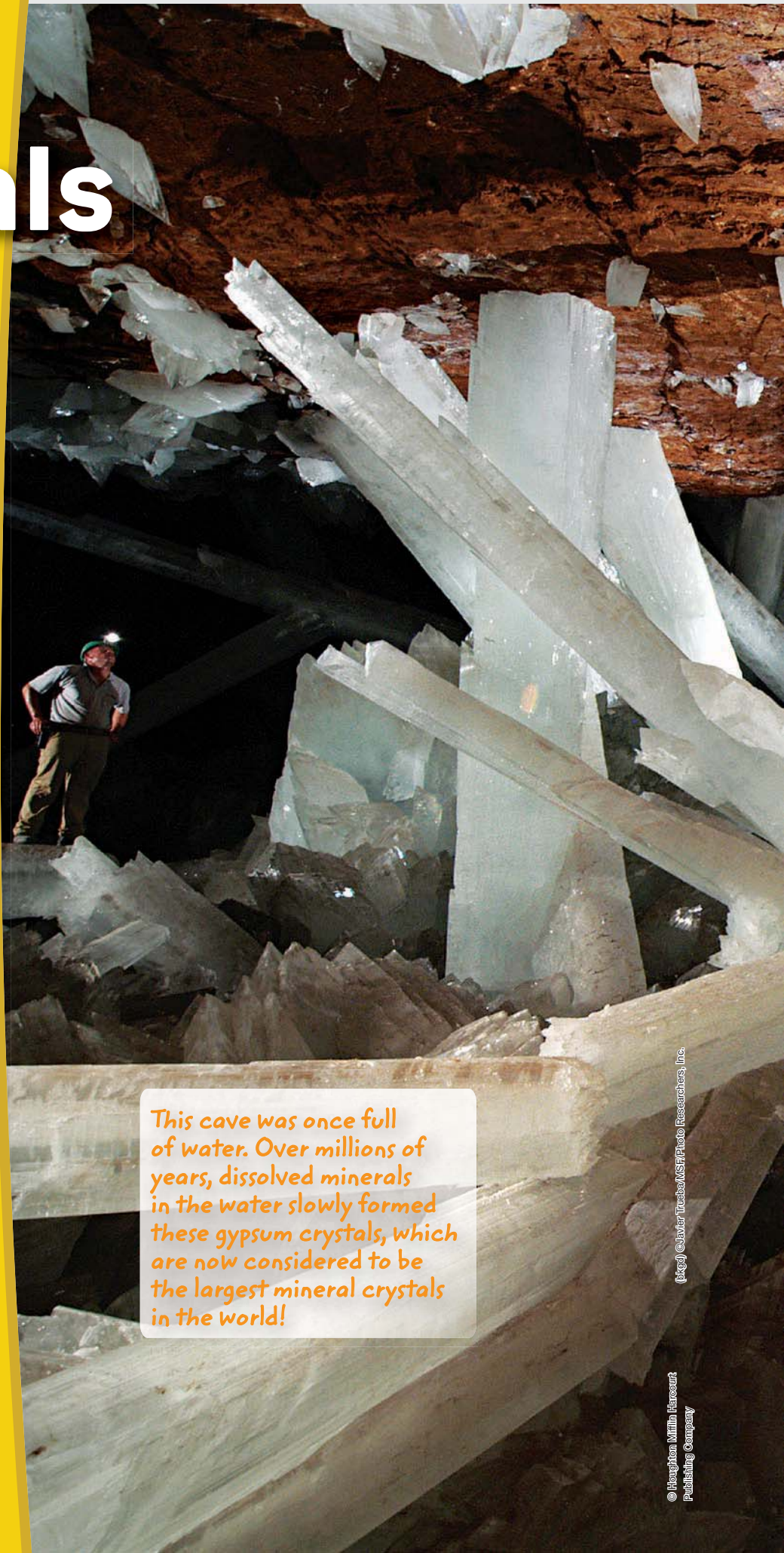
What major geological events have taken place where you live? What evidence exists to prove it? Explore evidence of geological activity.

Minerals

ESSENTIAL QUESTION

What are minerals, how do they form, and how can they be identified?

By the end of this lesson, you should be able to describe the basic structure of minerals and identify different minerals by using their physical properties.



This cave was once full of water. Over millions of years, dissolved minerals in the water slowly formed these gypsum crystals, which are now considered to be the largest mineral crystals in the world!



SC.7.E.6.2 Identify the patterns within the rock cycle and relate them to surface events (weathering and erosion) and sub-surface events (plate tectonics and mountain building).

Lesson Labs

Quick Labs

- Evaporation Rates
- Cooling Rate and Crystal Size
- Scratch Test

Exploration Lab

- Intrinsic Identification of Minerals

Engage Your Brain

1 Identify Which of the materials listed below is a mineral?

- | Yes | No | |
|--------------------------|--------------------------|------------|
| <input type="checkbox"/> | <input type="checkbox"/> | ice |
| <input type="checkbox"/> | <input type="checkbox"/> | gold |
| <input type="checkbox"/> | <input type="checkbox"/> | wood |
| <input type="checkbox"/> | <input type="checkbox"/> | diamond |
| <input type="checkbox"/> | <input type="checkbox"/> | table salt |

2 Explain Describe how you think the minerals in the picture below may have formed.



ACTIVE READING

3 Synthesize Many of this lesson's vocabulary terms are related to each other. Locate the terms in the Glossary and see if you can find connections between them. When you find two terms that are related to each other, write a sentence using both terms in a way that shows the relationship. An example is done for you.

Example Sentence

Each element is made of only one kind of atom.

Vocabulary Terms

- mineral
- crystal
- element
- streak
- atom
- luster
- compound
- cleavage
- matter

4 Apply As you learn the definition of each vocabulary term in this lesson, create your own definition or sketch to help you remember the meaning of the term.

Animal, Vegetable,

What do minerals have in common?

When you hear the word *mineral*, you may think of sparkling gems. But, in fact, most minerals are found in groups that make up rocks. So what is a mineral? A **mineral** is a naturally occurring, usually inorganic solid that has a definite crystalline structure and chemical composition.

○ Definite Chemical Composition

To understand what a definite chemical composition is, you need to know a little about elements. **Elements** are pure substances that cannot be broken down into simpler substances by ordinary chemical means. Each element is made of only one kind of atom. All substances are made up of atoms, so **atoms** can be thought of as the building blocks of matter. Stable particles that are made up of strongly bonded atoms are called *molecules*. And, if a substance is made up of molecules of two or more elements, the substance is called a **compound**.

The chemical composition of a mineral is determined by the element or compound that makes up the mineral. For example, minerals such as gold and silver are composed of only one element. Such a mineral is called a *native element*. The mineral quartz is a compound in which silicon atoms can each bond with up to four oxygen atoms in a repeating pattern.

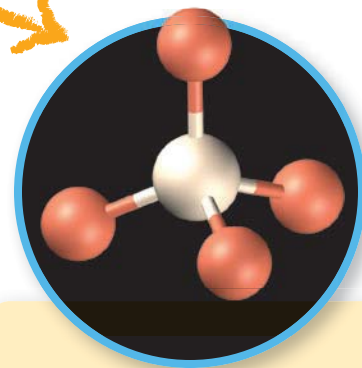
i **5 Claim • Evidence • Reasoning** Make a claim about the relationship between elements, atoms, and compounds. Summarize evidence to support the claim and explain your reasoning.

○ Solid

Matter is anything that has volume and mass.

Volume refers to the amount of space an object takes up. For example, a golf ball has a smaller volume than a baseball does. Matter is generally found in one of three states: solid, liquid, or gas. A mineral is a solid—that is, it has a definite volume and shape. A substance that is a liquid or a gas is not a mineral. However, in some cases its solid form is a mineral. For instance, liquid water is not a mineral, but ice is because it is solid and has all of the other mineral characteristics also.

Atoms The mineral quartz is made up of atoms of oxygen and silicon.



Compound An atom of silicon can typically bond with up to four oxygen atoms to form a molecule. One or more of these molecules form a compound.

(i) ©Bryan Dadsweil/Alamy

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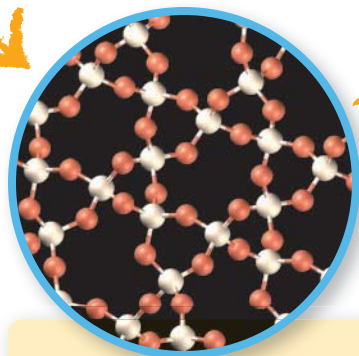
or Mineral?

Usually Inorganic

Most substances made by living things are categorized as organic substances, such as kidney stones and wood. However, a few substances made by animals, such as clam shells, are categorized as inorganic. An inorganic substance is usually one that is not made up of living things or the remains of living things. And, although a few organic substances such as kidney stones are categorized as minerals, most minerals are inorganic. And, unlike clam shells, most of the processes that form minerals usually take place in the non-living environment.

Crystalline Structure

Minerals have a crystalline structure because they are composed of crystals. A **crystal** is a solid, geometric form that results from a repeating pattern of atoms or molecules. A crystal's shape is produced by the arrangement of the atoms or molecules within the crystal. This arrangement is determined by the kinds of atoms or molecules that make up the mineral and the conditions under which it forms. All minerals can be placed into crystal classes according to their specific crystal shape. This diagram shows how silica compounds can be arranged in quartz crystals.



Crystal Structure In crystals, molecules are arranged in a regular pattern.



Mineral Crystal Billions of molecules arranged in a crystalline structure form these quartz crystals.

Naturally Occurring

Minerals are formed by many different natural processes that occur on Earth and throughout the universe. On Earth, the mineral halite, which is used for table salt, forms as water evaporates and leaves behind the salt it contained. Some minerals form as molten rock cools. Talc, a mineral that can be used to make baby powder, forms deep in Earth as high temperature and pressure change the rock. Some of the other ways in which minerals form are on the next page.

6 Classify Circle Y for “yes” or N for “no” to determine whether the two materials below are minerals.



	Cardboard	Topaz
Definite chemical composition?	Y <input checked="" type="radio"/> N	<input checked="" type="radio"/> Y N
Solid?	Y N	<input checked="" type="radio"/> Y N
Inorganic?	Y N	Y N
Naturally occurring?	Y N	Y N
Crystalline structure?	Y <input checked="" type="radio"/> N	Y N
Mineral?	Y N	Y N

Crystal Clear!

How are minerals formed?

Minerals form within Earth or on Earth's surface by natural processes. Recall that each type of mineral has its own chemical makeup. Therefore, which types of minerals form in an area depends in part on which elements are present there. Temperature and pressure also affect which minerals form.

○ As Magma and Lava Cool

Many minerals grow from magma. Magma—molten rock inside Earth—contains most of the types of atoms that are found in minerals. As magma cools, the atoms join together to form different minerals. Minerals also form as lava cools. Lava is molten rock that has reached Earth's surface. Quartz is one of the many minerals that crystallize from magma and lava.

○ By Metamorphism

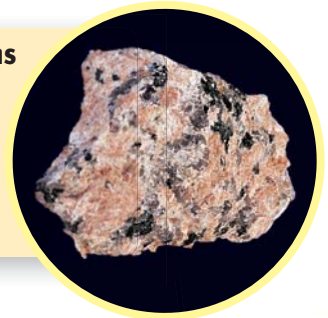
Temperature and pressure within Earth cause new minerals to form as bonds between atoms break and reform with different atoms. The mineral garnet can form and replace the minerals chlorite and quartz in this way. At high temperatures and pressures, the element carbon in rocks forms the mineral diamond or the mineral graphite, which is used in pencils.

👁 Visualize It!

7 Claims • Evidence • Reasoning Make a claim about the ways in which pluton and pegmatite form in a similar fashion. Summarize evidence to support the claim and explain your reasoning.

Cooling Magma Forms Plutons

As magma rises, it can stop moving and cool slowly. This forms rocks like this granite, which contains minerals like quartz, mica, and feldspar.



Cooling Magma Forms Pegmatites

Magma that cools very slowly can form pegmatites. Some crystals in pegmatites, such as this topaz, can grow quite large.



Metamorphism Minerals like these garnets form when temperature and pressure causes the chemical and crystalline makeup of minerals to change.



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From Solutions

Water usually has many substances dissolved in it. As water evaporates, these substances form into solids and come out of solution, or *precipitate*. For example, the mineral gypsum often forms as water evaporates. Minerals can also form from hot water solutions. Hot water can dissolve more materials than cold water. As a body of hot water cools, dissolved substances can form into minerals such as dolomite, as they precipitate out of solution.

8 Summarize Describe three ways minerals form.

A _____

B _____

C _____

Precipitating from an Evaporating Solution When a body of salt water evaporates, minerals such as this halite precipitate and are left behind on the shoreline.



Precipitating from a Cooling Solution on Earth's Surface Dissolved materials can come out of a solution and accumulate. Dolomite, can form this way.



Precipitating from a Cooling Solution Beneath Earth's Surface Water works its way downward and is heated by magma. It then reacts with minerals to form a solution. Dissolved elements, such as gold, precipitate once the fluid cools to form new mineral deposits.

Think Outside the Book

9 Apply Find out what your state mineral is and how it forms.

Sort It Out

How are minerals classified?

The most common classification of minerals is based on chemical composition. Minerals are divided into two groups based on their composition. These groups are the silicate (SIL'ih•kayt) minerals and the nonsilicate (nawn•SIL'ih•kayt) minerals.

Silicate Minerals

Silicon and oxygen are the two most common elements in Earth's crust. Minerals that contain a combination of these two elements are called *silicate minerals*. Silicate minerals make up most of Earth's crust. The most common silicate minerals in Earth's crust are feldspar and quartz. Most silicate minerals are formed from basic building blocks called *silicate tetrahedrons*. Silicate tetrahedrons are made of one silicon atom bonded to four oxygen atoms. Most silicate minerals, including mica and olivine, are composed of silicate tetrahedrons combined with other elements, such as aluminum or iron.

ACTIVE READING

10 Claims • Evidence • Reasoning Make a claim about why Earth's crust is made up mostly of silicate materials. Summarize evidence to support the claim and explain your reasoning.

The mineral zircon is a silicate mineral. It is composed of the element zirconium and silicate tetrahedrons.

Nonsilicate Minerals

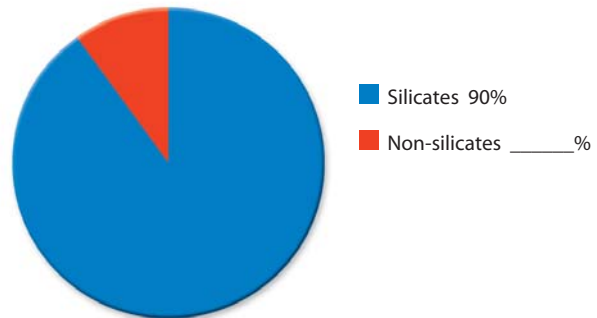
Minerals that do not contain the silicate tetrahedron building block form a group called the *nonsilicate minerals*. Some of these minerals are made up of elements such as carbon, oxygen, fluorine, iron, and sulfur. The table on the next page shows the most important classes of nonsilicate minerals. A nonsilicate mineral's chemical composition determines its class.

Do the Math

You Try It

11 Calculate Calculate the percent of non-silicates in Earth's crust to complete the graph's key.

Minerals in Earth's Crust



Classes of Nonsilicate Minerals

Native elements are minerals that are composed of only one element. Copper (Cu) and silver (Ag) are two examples. Native elements are often used to make electronics.



Silver, Ag

Carbonates are minerals that contain carbon (C) and oxygen (O) in the form of the carbonate ion CO_3^{2-} . We use carbonate minerals in cement, building stones, and fireworks.



Calcite, CaCO_3

Halides are compounds that form when elements such as fluorine (F) and chlorine (Cl), combine with elements such as calcium (Ca). Halides are used in the chemical industry and in detergents.



Fluorite, CaF_2

Oxides are compounds that form when an element, such as aluminum (Al) or iron (Fe), combines with oxygen. Oxide minerals are used to make abrasives, aircraft parts, and paint.



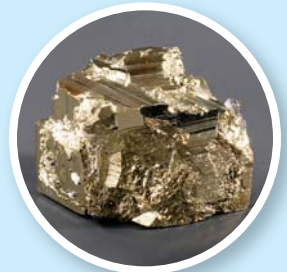
Corundum, Al_2O_3

Sulfates are minerals that contain sulfur (S) and oxygen (O) in the form of the sulfate ion SO_4^{2-} . Sulfates are used in cosmetics, toothpaste, cement, and paint.



Barite, BaSO_4

Sulfides are minerals that contain one or more elements, such as lead (Pb), or iron (Fe), combined with sulfur (S). Sulfide minerals are used to make batteries and medicines.



Pyrite, FeS_2

Visualize It!

12 Classify Examine the chemical formulas for the two minerals on the right. Classify each mineral as a silicate or a nonsilicate. If it is a nonsilicate, also write its class.

Gypsum, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$



Kyanite, Al_2SiO_5



Name That Mineral!

What properties can be used to identify minerals?

If you closed your eyes and tasted different foods, you could probably determine what the foods are by noting properties such as saltiness or sweetness. You can also determine the identity of a mineral by noting different properties. In this section, you will learn about the properties that will help you identify minerals.

○ Color

The same mineral can come in different colors. For example, pure quartz is colorless. However, impurities can make quartz pink, orange, or many other colors. Other factors can also change a mineral's color. Pyrite is normally golden, but turns black or brown if exposed to air and water. The same mineral can be different colors, and different minerals can be the same color. So, color is helpful but usually not the best way to identify a mineral.

○ Streak

The color of the powdered form of a mineral is its **streak**. A mineral's streak is found by rubbing the mineral against a white tile called a *streak plate*. The mark left is the streak. A mineral's streak is not always the same as the color of the mineral, but all samples of the same mineral have the same streak color. Unlike the surface of a mineral, the streak is not affected by air or water. For this reason, streak is more reliable than color in identifying a mineral.

ACTIVE READING

13 Identify Underline the name of the property on this page that is most reliable for identifying a mineral.

👁 Visualize It!

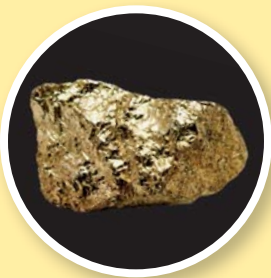
14 Claims • Evidence • Reasoning

Look at these two mineral samples. Make a claim about which property indicates that the two minerals might be the same mineral. Summarize evidence to support the claim and explain your reasoning.

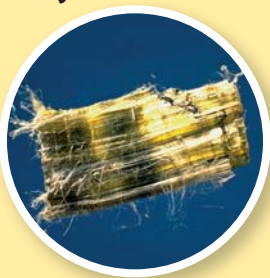


Mineral Lusters

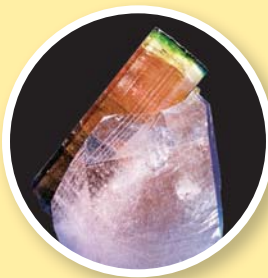
Metallic



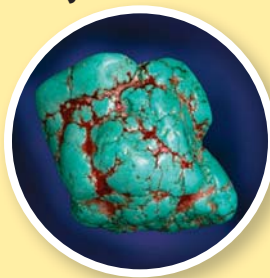
Silky



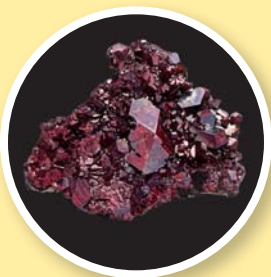
Vitreous



Waxy



Submetallic



Pearly



Resinous



Earthy



Getty Images; (pearly) ©GC Minerals/Alamy; (resinous) ©Andrey Semenov/Hemera/Getty Images Plus/
Getty Images; (earthy) ©Leslie Garland Picture Library/Alamy; (br) ©USGS

Luster

The way a surface reflects light is called **luster**. When you say an object is shiny or dull, you are describing its luster. The two major types of luster are metallic and nonmetallic. Pyrite has a metallic luster. It looks as if it is made of metal. A mineral with a nonmetallic luster can be shiny, but it does not appear to be made of metal. Different types of lusters are shown above.

Cleavage and Fracture

The tendency of a mineral to split along specific planes of weakness to form smooth, flat surfaces is called **cleavage**. When a mineral has cleavage, it breaks along flat surfaces that generally run parallel to planes of weakness in the crystal structure. For example, mica tends to split into parallel sheets. Many minerals, however, do not break along cleavage planes. Instead, they fracture, or break unevenly, into pieces that have curved or irregular surfaces. Scientists describe a fracture according to the appearance of the broken surface. For example, a rough surface has an irregular fracture, and a curved surface has a conchoidal (kahn•KOY•duhl) fracture.

Visualize It!

15 Identify Write the correct description, either *cleavage* or *fracture*, under the two broken mineral crystals shown here.



(metallic) ©Steve Sant/Alamy; (silky) ©Lester V. Bergman/Corbis; (vitreous) ©Joel Arem/Photo
Researchers, Inc.; (waxy) ©Sciences & Science/Alamy; (submetallic) ©Harry Taylor/Dorling Kindersley/

Mohs Scale

1 Talc

2 Gypsum

3 Calcite

4 Fluorite

5 Apatite

6 Feldspar

7 Quartz

8 Topaz

9 Corundum

10 Diamond



Your fingernail has a hardness of about 2.5, so it can scratch talc and gypsum.



A steel file has a hardness of about 6.5. You can scratch feldspar with it.



Diamond is the hardest mineral. Only a diamond can scratch another diamond.

Visualize It!

16 Determine A mineral can be scratched by calcite but not by a fingernail. What is its approximate hardness?

Density

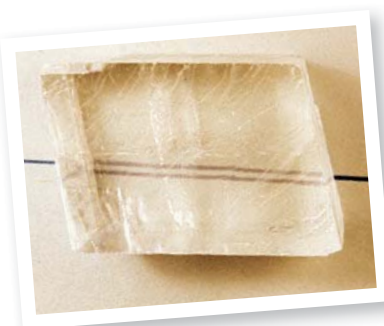
If you pick up a golf ball and a table-tennis ball, which will feel heavier? Although the balls are of similar size, the golf ball will feel heavier because it is denser. *Density* is the measure of how much matter is in a given amount of space. Density is usually measured in grams per cubic centimeter. Gold has a density of 19 g/cm^3 . The mineral pyrite looks very similar to gold, but its density is only 5 g/cm^3 . Because of this, density can be used to tell gold from pyrite. Density can also be used to tell many other similar-looking minerals apart.

Hardness

A mineral's resistance to being scratched is called its *hardness*. To determine the hardness of minerals, scientists use the Mohs hardness scale, shown at left. Notice that talc has a rating of 1 and diamond has a rating of 10. The greater a mineral's resistance to being scratched, the higher its hardness rating. To identify a mineral by using the Mohs scale, try to scratch the surface of a mineral with the edge of one of the 10 reference minerals. If the reference mineral scratches your mineral, the reference mineral is as hard as or harder than your mineral.

Special Properties

All minerals exhibit the properties that were described earlier in this section. However, a few minerals have some additional, special properties that can help identify those minerals. For example, the mineral magnetite is a natural magnet. The mineral calcite is usually white in ordinary light, but in ultraviolet light, it often appears red. Another special property of calcite is shown below.



A clear piece of calcite placed over an image will cause a double image.

WHY IT MATTERS

Made from Minerals

SOCIETY AND
TECHNOLOGY

Many minerals contain useful substances. Rutile and several other minerals contain the metal titanium. Titanium can resist corrosion and is about as strong as steel, but it is 47% lighter than steel. These properties make titanium very valuable.



Devices for Doctors

Surgical procedures like joint replacements require metal implantations. Titanium is used because it can resist body fluid corrosion and its low density and elasticity are similar to human bone.

An Aid to Architects

Titanium doesn't just serve practical purposes. Architect Frank Gehry used titanium panels to cover the outside of the Guggenheim Museum in Bilbao, Spain. He chose titanium because of its luster.

Marvels for Mechanics

Motorcycle exhaust pipes are often made out of titanium, which dissipates heat better than stainless steel.



i Extend

17 Claims • Evidence • Reasoning Make a claim about how the density of titanium-containing minerals would compare to the density of minerals used to make steel. Use evidence to support the claim and explain your reasoning.

18 List Research some other products made from minerals. Make a list summarizing your research.

19 Determine Choose one of the products you researched. How do the properties of the minerals used to make the product contribute to the product's characteristics or usefulness?

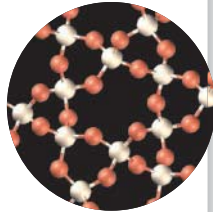
Visual Summary

To complete this summary, fill in the blanks with the correct words or phrase. You can use this page to review the main concepts of the lesson.

Minerals make up Earth's crust.

20 A mineral:

- has a definite chemical composition
- is a solid
- is usually inorganic
- is formed in nature
- _____



Minerals are classified by composition.

21 Minerals are classified in two groups as:

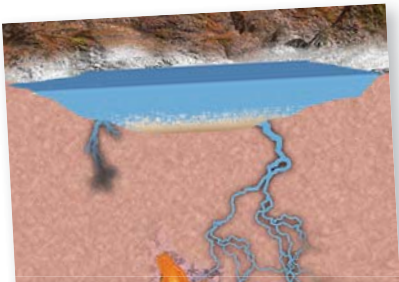


Quartz, SiO_2



Calcite, CaCO_3

Minerals



Minerals form by natural processes.

22 Minerals form by:

- metamorphism
- the cooling of magma and lava
- _____

Minerals are identified by their properties.

23 Properties used to identify minerals include:

- color and luster
- _____
- cleavage or fracture
- density and hardness
- special properties



24 **Claims • Evidence • Reasoning** Make a claim as to whether ice (H_2O) is a silicate or nonsilicate. Summarize evidence to support the claim and explain your reasoning.

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Vocabulary

Fill in the blank with the term that best completes the following sentence.

- 1 The way light bounces off a mineral's surface is described by the mineral's _____
- 2 The color of a mineral in powdered form is the mineral's _____
- 3 Each element is made up of only one kind of _____

Key Concepts

- 4 Explain** How could you determine whether an unknown substance is a mineral?

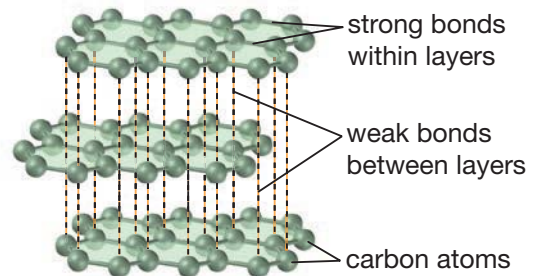
- 5 Determine** If a substance is a mineral, how could you identify what type of mineral it is?

- 6 Organize** In the space below, draw a graphic organizer showing how minerals can be classified. Be sure to include the six main classes of nonsilicate minerals.

Critical Thinking

Use the diagram below to answer question 7.

Carbon Bonds in Graphite



- 7 Claims • Evidence • Reasoning** The diagram above shows the crystal structure of graphite, a mineral made up of carbon atoms that are bonded together in a regular pattern. Make a claim about whether graphite would more likely display cleavage or fracture. Summarize evidence to support the claim and explain your reasoning.

- 8 Infer** How do you think the hardness and density of a mineral that formed through metamorphism would compare to a mineral that formed through evaporation? Explain your reasoning.



Florida Minerals



The Tallahassee courthouse is made of limestone, which is common throughout Florida.



Calcite in Limestone

Calcite is the primary mineral in limestone. Florida is the second largest producer of limestone in the United States. Most of the limestone mined in Florida is used for road construction. Limestone can also be used to produce cement, glass, and ceramics. Florida's limestone formed over millions of years. Sediment made up of the hard body parts of marine organisms was deposited in thick layers. These layers were later compressed to form limestone.

A key part of the mining process for limestone is following standards to help protect natural resources. The standards include using minimum amounts of water, replanting trees, and making sure an area is not overmined.

Mining

Sandstone, calcite, gypsum, and kaolin are some of the common minerals found in Florida. Kaolin is a clay that is used to make paper, rubber, and china. It is mined mostly in east-central Florida. Kaolin miners drill holes and take samples to locate kaolin deposits. If a deposit is large enough and is of good quality, mining can start. First, the layers of earth above the kaolin are removed—as deep as 30 m. The crude kaolin material is sent to a processing plant where it is dried and separated from other materials. Afterward, the dried kaolin is sent to roller mills, where it is ground into a fine powder. It is then packaged and sent off to manufacturers to make a variety of products. Kaolin can be hazardous. Studies have found that long-term exposure to kaolin may cause miners to develop a respiratory disease called *kaolinosis*.

Social Studies Connection

Use your school library or the Internet to learn about the state stone of Florida and the minerals it contains. Mark the locations where it can be found on the map shown.



Take It Home

With an adult, find three items in your home that are made from minerals. List the minerals they contain, and research whether these minerals can be found in Florida.



Phosphate Minerals

Florida's phosphate industry supplies one-fourth of the world's phosphate needs. Mining for phosphate rock, which is rich in phosphate minerals, began in 1883 in Florida. Phosphate is mainly used to make fertilizer, but it is also used in other things, such as vitamins, soft drinks, and even toothpaste!

Like limestone, phosphate rock is formed from sediments of marine organisms deposited on the ocean floor. It is found in a layer of sediment located about 5–15 m below Earth's

surface. To get to this layer, miners use a dragline to remove the soil above the layer. The layer is transported to a pit, where it is processed. The phosphate is separated from sediments like sand and clay.

Phosphate mining primarily uses fluoride, radon gas, and sulfur dioxide for processing. These chemicals can be dangerous to the environment and humans. Recent regulations have been put in place to control and reduce the harmful effects of phosphate mining.

This dragline is being used to mine phosphate in Florida.



The Rock Cycle

ESSENTIAL QUESTION

What is the rock cycle?

By the end of this lesson, you should be able to describe the series of processes and classes of rocks that make up the rock cycle.



SC.7.E.6.2 Identify the patterns within the rock cycle and relate them to surface events (weathering and erosion) and sub-surface events (plate tectonics and mountain building).

It may be hard to believe, but these mountains actually move. Wyoming's Teton Mountains rise by millimeters each year. An active fault is uplifting the mountains. In this lesson, you will learn about uplift and other processes that change rock.

Lesson Labs

Quick Lab

- Crayon Rock Cycle
- Compression

S.T.E.M. Lab

- Modeling Rock Formation



Engage Your Brain

- 1 Describe** Fill in the blank with the word or phrase that you think correctly completes the following sentences.

Most of Earth is made of _____

Rock is _____ changing.

The three main classes of rock are igneous, metamorphic, and _____

- 2 Describe** Write your own caption for this photo.



ACTIVE READING

- 3 Synthesize** Many English words have their roots in other languages. Use the Latin words below to make an educated guess about the meaning of the words *erosion* and *deposition*.

Latin Word	Meaning
<i>erosus</i>	eaten away
<i>depositus</i>	laid down

Erosion:

Deposition:

Vocabulary Terms

- weathering
- erosion
- deposition
- igneous rock
- sedimentary rock
- metamorphic rock
- rock cycle
- uplift
- subsidence
- rift zone

- 4 Apply** As you learn the definition of each vocabulary term in this lesson, create your own definition or sketch to help you remember the meaning of the term.

Let's Rock!

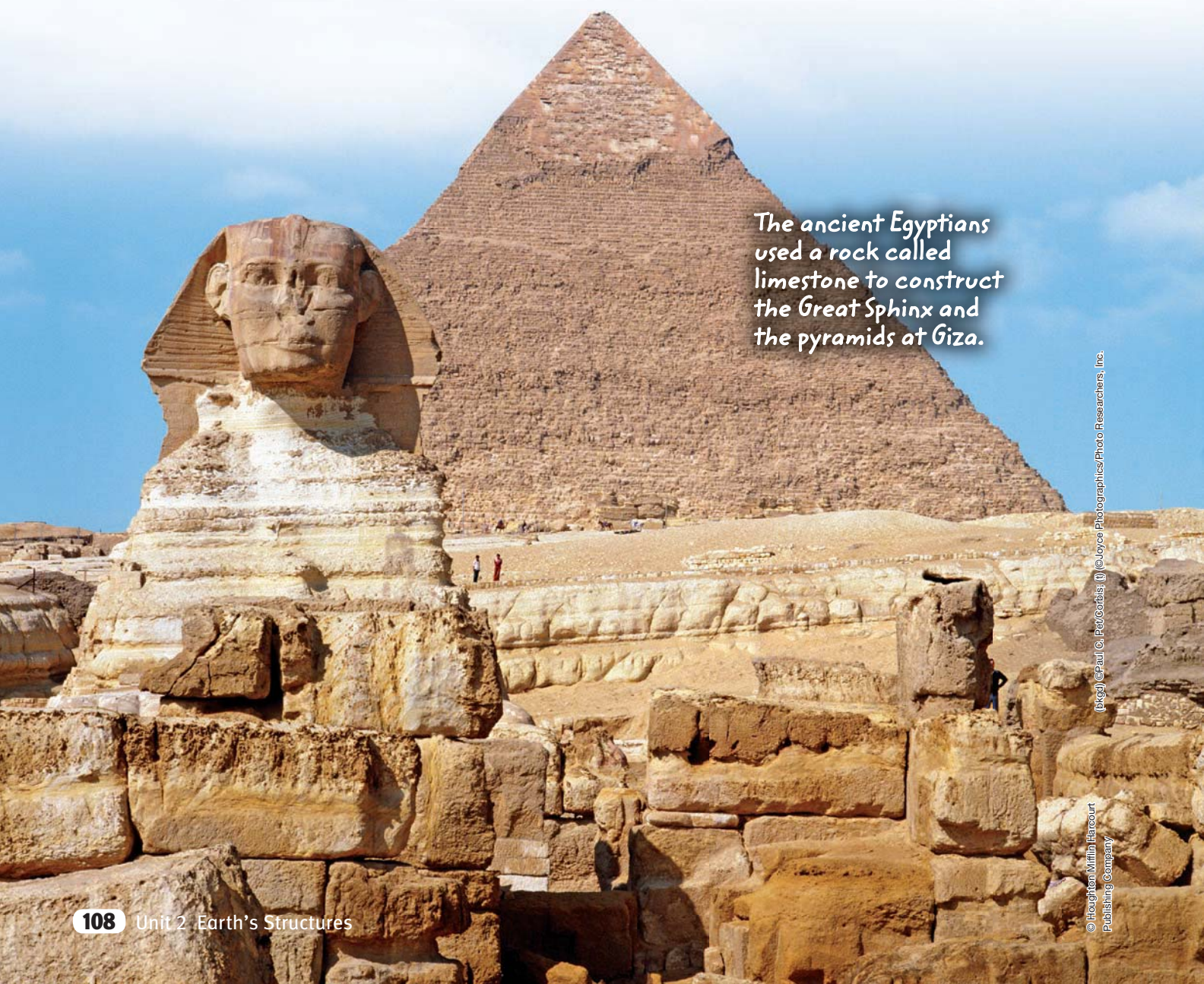
What is rock?

The solid parts of Earth are made almost entirely of rock. Scientists define rock as a naturally occurring solid mixture of one or more minerals that may also include organic matter. Most rock is made of minerals, but some rock is made of nonmineral material that is not organic, such as glass. Rock has been an important natural resource as long as humans have existed. Early humans used rocks as hammers to make other tools. For centuries, people have used different types of rock, including granite, marble, sandstone, and slate, to make buildings, such as the pyramids shown below.

It may be hard to believe, but rocks are always changing. People study rocks to learn how areas have changed through time.

5 List How is rock used today?

The ancient Egyptians used a rock called limestone to construct the Great Sphinx and the pyramids at Giza.



(Image) © Paul G. Pez/Gorlaia (i) ©Joyce Photographics/Photo Researchers, Inc.

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These rock formations in Goreme, Turkey, are known as fairy chimneys. They were shaped by erosion.

Think Outside the Book

6 Design Create a travel brochure for Goreme, Turkey.

What processes change rock?

Natural processes make and destroy rock. They change each type of rock into other types of rock and shape the features of our planet. These processes also influence the type of rock that is found in each area of Earth's surface.

ACTIVE READING

7 Identify As you read, underline the processes and factors that can change rock.

Weathering, Erosion, and Deposition

The process by which water, wind, ice, and changes in temperature break down rock is called **weathering**. Weathering breaks down rock into fragments called *sediment*. The process by which sediment is moved from one place to another is called **erosion**. Water, wind, ice, and gravity can erode sediments. These sediments are eventually deposited, or laid down, in bodies of water and other low-lying areas. The process by which sediment comes to rest is called **deposition**.

Temperature and Pressure

Rock that is buried can be squeezed by the weight of the rock or the layers of sediment on top of it. As pressure increases with depth beneath Earth's surface, so does temperature. If the temperature and pressure are high enough, the buried rock can change into metamorphic rock. In some cases, the rock gets hot enough to melt and forms *magma*, or molten rock. If magma reaches Earth's surface, it is called *lava*. The magma or lava eventually cool and solidify to form new rock.

Classified Information!

What are the classes of rocks?

Rocks fall into three major classes based on how they form.

Igneous rock forms when magma or lava cools and hardens to become solid. It forms beneath or on Earth's surface. **Sedimentary rock** forms when minerals that form from solutions or sediment from older rocks get pressed and cemented together. **Metamorphic rock** forms when pressure, temperature, or chemical processes change existing rock. Each class can be divided further, based on differences in the way rocks form. For example, some igneous rocks form when lava cools on Earth's surface, and others form when magma cools deep beneath the surface. Therefore, igneous rock can be classified based on how and where it forms.

ACTIVE READING

8 Identify As you read the paragraph, underline the three main classes of rocks.

i Think Outside the Book

9 Claims • Evidence • Reasoning

Make a claim about the processes that might have shaped the rock formations in the Valley of Fire State Park. Summarize evidence to support the claim and explain your reasoning.

Sedimentary Rock

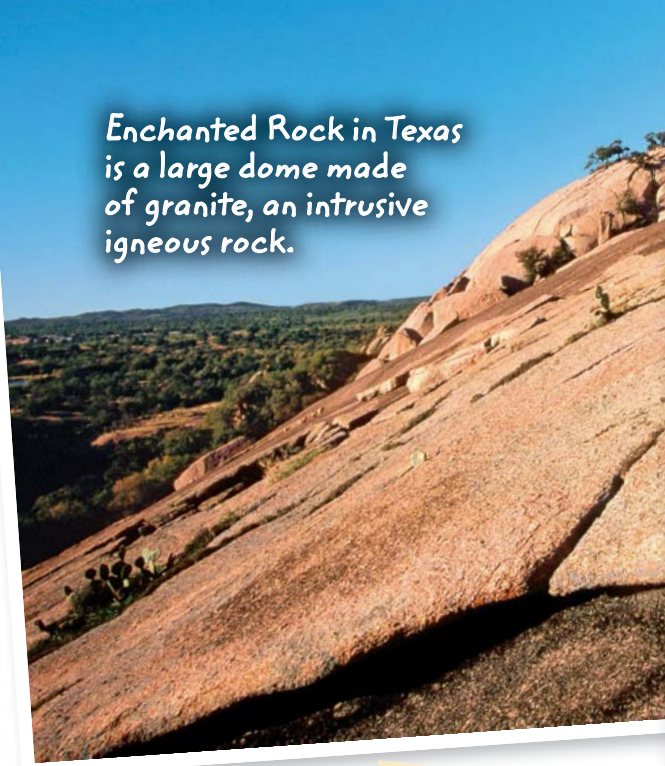
Sedimentary rock is composed of minerals formed from solutions or sediments from older rock. Sedimentary rock forms when the weight from above presses down on the layers of minerals or sediment, or when minerals dissolved in water solidify between sediment pieces and cement them together.

Sedimentary rocks are named according to the size and type of the fragments they contain. For example, the rock shown here is made of sand and is called sandstone. Rock made primarily of the mineral calcite (calcium carbonate) is called limestone.

sandstone

These formations in Valley of Fire State Park in Nevada are made of sandstone, a sedimentary rock.

Enchanted Rock in Texas is a large dome made of granite, an intrusive igneous rock.



Igneous Rock

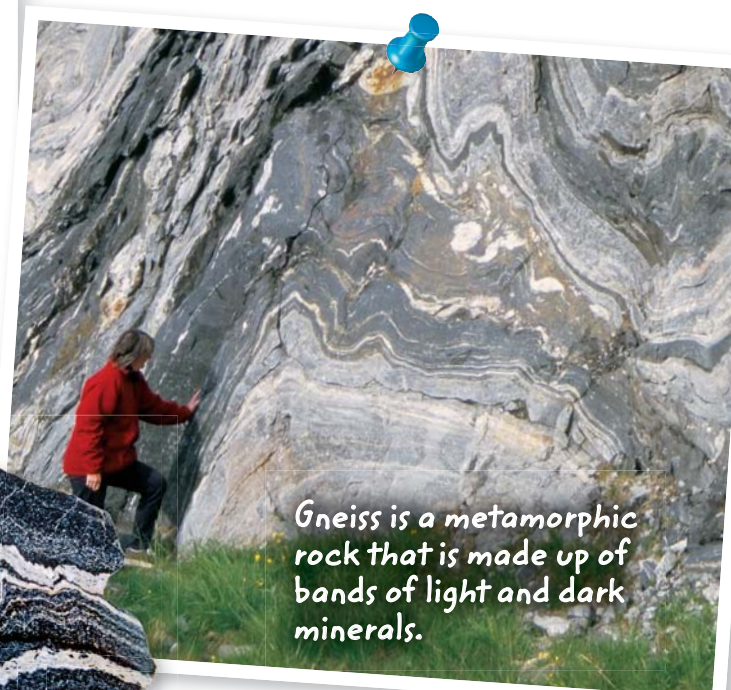
Igneous rock forms from cooling lava and magma. As molten rock cools and becomes solid, the minerals crystallize and grow. The longer the cooling takes, the more time the crystals have to grow. The granite shown here cooled slowly and is made of large crystals. Rock that forms when magma cools beneath Earth's surface is called intrusive igneous rock. Rock that forms when lava cools on Earth's surface is called extrusive igneous rock.



granite

Metamorphic Rock

Metamorphic rock forms when high temperature and pressure change the texture and mineral content of rock. For example, a rock can be buried in Earth's crust, where the temperature and pressure are high. Over millions of years, the solid rock changes, and new crystals are formed. Metamorphic rocks may be changed in four ways: by temperature, by pressure, by temperature and pressure combined, or by fluids or other chemicals. Gneiss, shown here, is a metamorphic rock. It forms at high temperatures deep within Earth's crust.



gneiss

Gneiss is a metamorphic rock that is made up of bands of light and dark minerals.

10 Compare Fill in the chart to compare and contrast sedimentary, igneous, and metamorphic rock.

Classes of Rocks

Sedimentary rock	Igneous rock	Metamorphic rock

What is the rock cycle?

ACTIVE READING

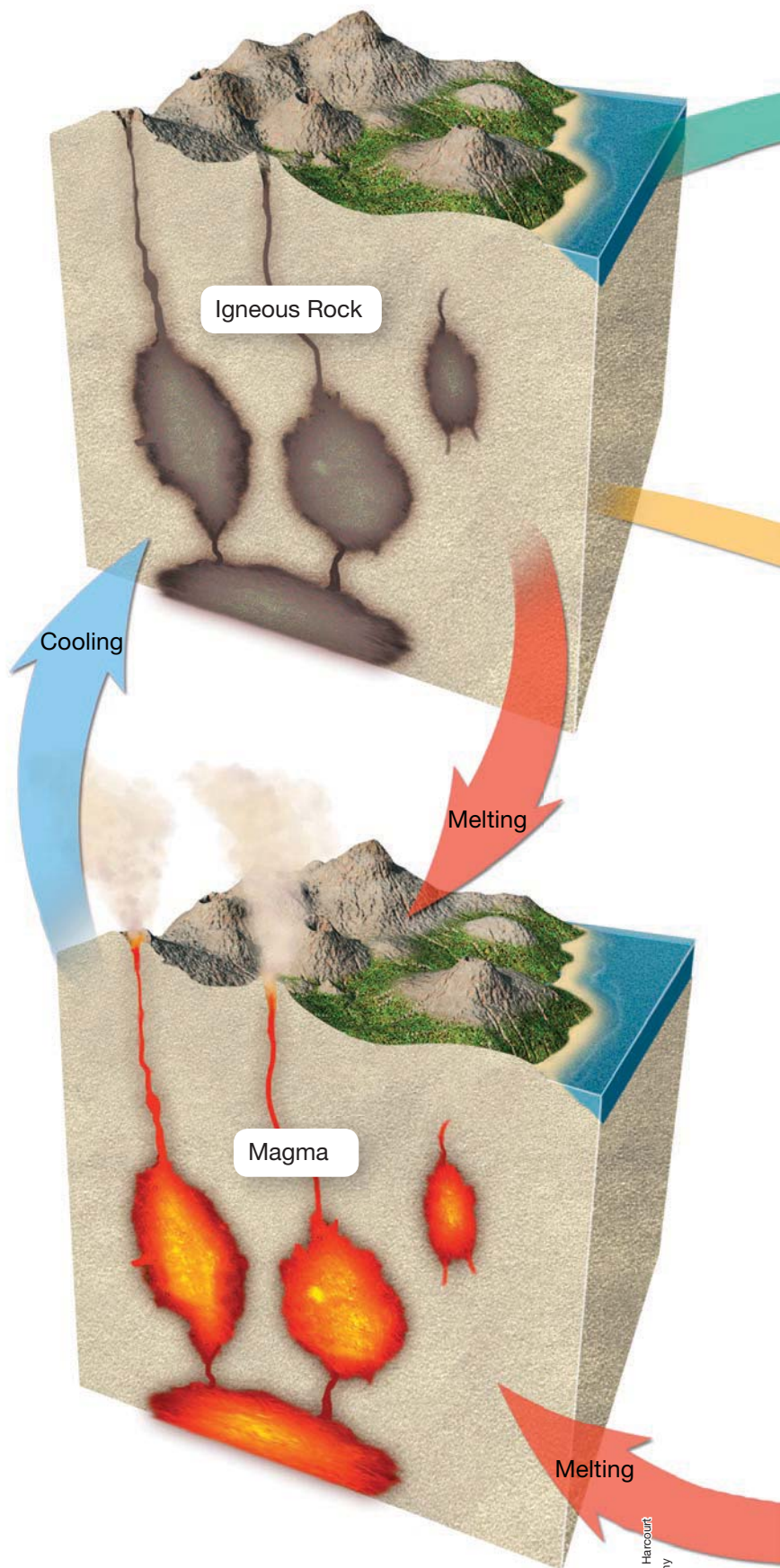
11 Apply As you read, underline the rock types that metamorphic rock can change into.

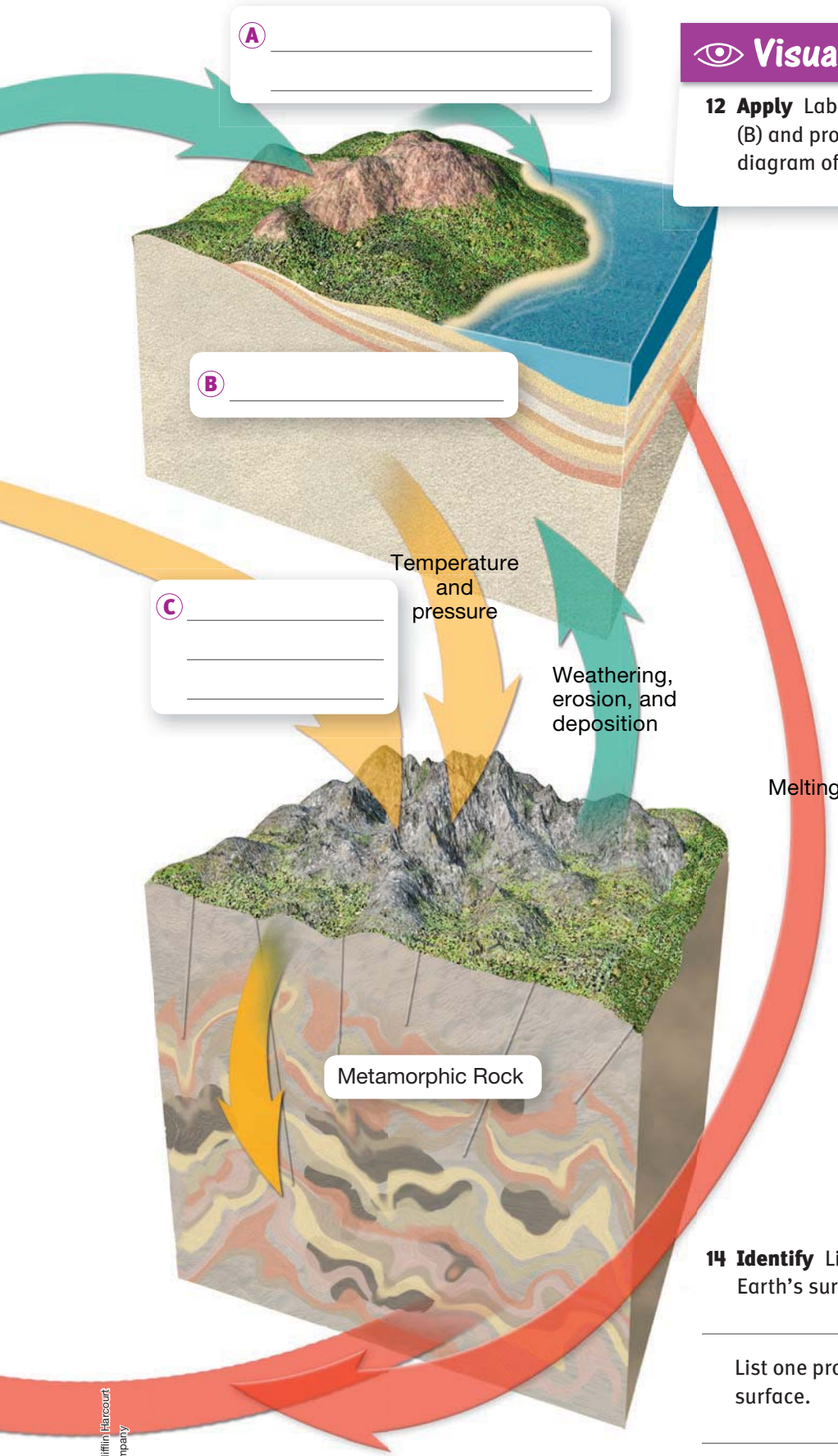
Rocks may seem very permanent, solid, and unchanging. But over millions of years, any of the three rock types can be changed into another of the three types. For example, igneous rock can change into sedimentary or metamorphic rock, or back into another kind of igneous rock. This series of processes in which rock changes from one type to another is called the **rock cycle**. Rocks may follow different pathways in the cycle. Examples of these pathways are shown here. Factors, including temperature, pressure, weathering, and erosion, may change a rock's identity. Where rock is located on a tectonic plate and whether the rock is at Earth's surface also influence how it forms and changes.

When igneous rock is exposed at Earth's surface, it may break down into sediment. Igneous rock may also change directly into metamorphic rock while still beneath Earth's surface. It may also melt to form magma that becomes another type of igneous rock.

When sediment is pressed together and cemented, the sediment becomes sedimentary rock. With temperature and pressure changes, sedimentary rocks may become metamorphic rocks, or they may melt and become igneous rock. Sedimentary rock may also be broken down at Earth's surface and become sediment that forms another sedimentary rock.

Under certain temperature and pressure conditions, metamorphic rock will melt and form magma. Metamorphic rock can also be altered by heat and pressure to form a different type of metamorphic rock. Metamorphic rock can also be broken down by weathering and erosion to form sediment that forms sedimentary rock.





A _____

Visualize It!

12 Apply Label the missing rock type (B) and processes (A and C) on the diagram of the rock cycle.

B _____

C _____

Temperature and pressure

Weathering, erosion, and deposition

Melting

Metamorphic Rock

Think Outside the Book

13 Apply Write a series of blog entries from the viewpoint of igneous rock that is changing into sedimentary rock.

14 Identify List one process that happens above Earth's surface.

List one process that happens below Earth's surface.

How do tectonic plate motions affect the rock cycle?

Tectonic plate motions can move rock around. Rock that was beneath Earth's surface may become exposed to wind and rain. Sediment or rock on Earth's surface may be buried. Rock can also be changed into metamorphic rock by tectonic plate collisions because of increased temperature and pressure.

○ By Moving Rock Up or Down

There are two types of vertical movements in Earth's crust: uplift and subsidence. **Uplift** is the rising of regions of the crust to higher elevations. Uplift increases the rate of erosion on rock. **Subsidence** is the sinking of regions of the crust to lower elevations. Subsidence leads to the formation of basins where sediment can be deposited.

○ By Pulling Apart Earth's Surface

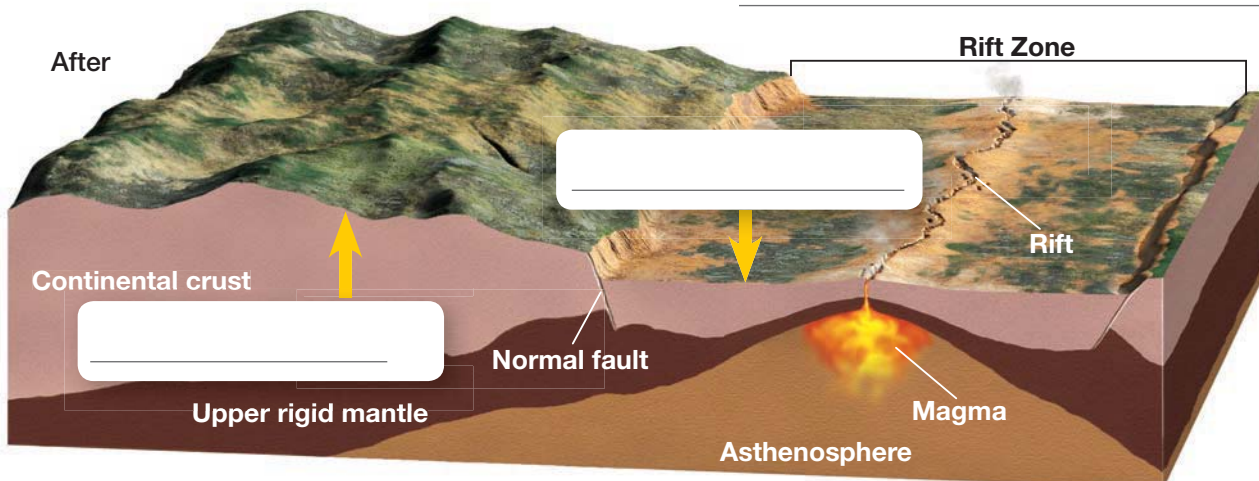
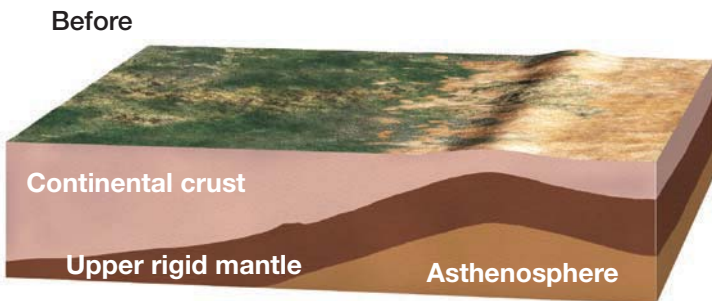
A **rift zone** is an area where a set of deep cracks form. Rift zones are common between tectonic plates that are pulling apart. As they pull apart, blocks of crust in the center of the rift zone subside and the pressure on buried rocks is reduced. The reduction in pressure allows rock below Earth's surface to rise up. As the rock rises, it undergoes partial melting and forms magma. Magma can cool below Earth's surface to form igneous rock. If it reaches the surface, magma becomes lava, which can also cool to form igneous rock.

15 Claims • Evidence • Reasoning

Make a claim about how uplift differs from subsidence. Summarize evidence to support the claim and explain your reasoning.

👁 Visualize It!

16 Claims • Evidence • Reasoning Label uplift and subsidence on this diagram. Make a claim about what pathway in the rock cycle might take next if it is subject to uplift. Use evidence to support the claim and explain your reasoning.



WHY IT MATTERS

Cliff Dwellings

WEIRD
SCIENCE

Can you imagine living on the side of a cliff? Some ancient peoples could! They created dwellings from cliff rock. They also decorated rock with art, as you can see in the pictographs shown below.

Cliff Palace

This dwelling in Colorado is called the Cliff Palace. It was home to the Ancient Puebloans from about 550 to 1300 CE.

Cliff Art

These pictographs are located at the Gila Cliff Dwellings in New Mexico.

A Palace in Rock

Ancient cliff dwellings are also found outside the United States. These dwellings from about 70 CE are located in Petra, Jordan.

i Extend

17 Claims • Evidence • Reasoning Make a claim about how ancient people used rock to create shelter. Summarize evidence to support the claim and explain your reasoning.

18 Research Find out how people lived in one of

the cliff dwelling locations. How did living in a rock environment affect their daily lives?

19 Produce Illustrate how the people lived by doing one of the following: write a play, write a song, or create a graphic novel.

Visual Summary

To complete this summary, use what you know about the rock cycle to fill in the blanks below. You can use this page to review the main concepts of the lesson.

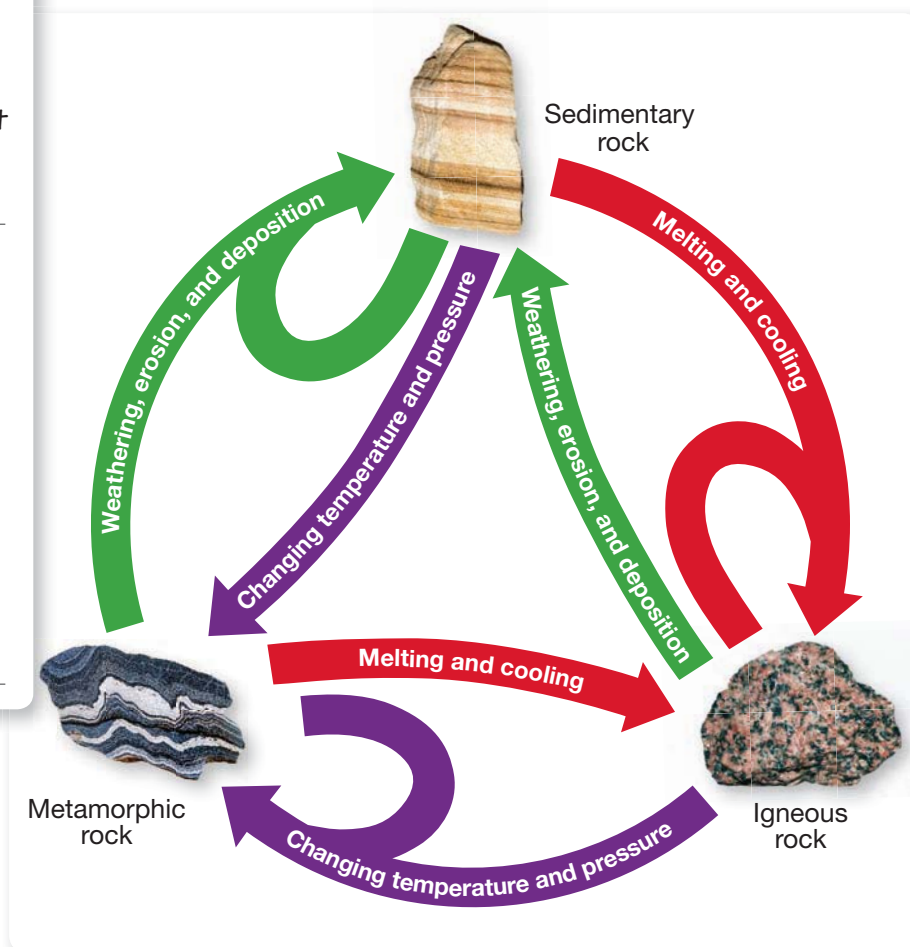
Each rock type can change into another of the three types.

20 When sediment is pressed together and cemented, the sediment becomes _____

21 When lava cools and solidifies, _____ forms.

22 Metamorphic rock can be altered by temperature and pressure to form a different type of _____

Rock Cycle



23 Claims • Evidence • Reasoning Make a claim about what factors and processes can affect the pathway that igneous rock takes in the rock cycle. Summarize evidence to support the claim and explain your reasoning.

(sedimentary) ©Joyce Photographics/Photo Researchers, Inc.; (morphig) ©Dik Wiersma/Photo Researchers, Inc.; (igneous) ©Joyce Photographics/Photo Researchers, Inc.

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Vocabulary

In your own words, define the following terms.




1 Rock cycle

2 Weathering

3 Rift zone

Key Concepts

Use these photos to classify the rock as sedimentary, igneous, or metamorphic.

Example	Type of rock
<p>4 Classify This rock is made up of the mineral calcite, and it formed from the remains of organisms that lived in water.</p>	
<p>5 Classify Through high temperature and pressure, this rock formed from a sedimentary rock.</p>	
<p>6 Classify This rock is made of tiny crystals that formed quickly when molten rock cooled at Earth's surface.</p>	

7 Describe How can sedimentary rock become metamorphic rock?

8 Explain How can subsidence lead to the formation of sedimentary rock?

9 Explain Why are rift zones common places for igneous rock to form?

Critical Thinking

10 Claims • Evidence • Reasoning Make a claim about what would happen to the rock cycle if erosion did not occur. Summarize evidence to support the claim and explain your reasoning.

11 Criticize A classmate states that igneous rock must always become sedimentary rock next, according to the rock cycle. Explain why this statement is not correct.

12 Claims • Evidence • Reasoning Granite is an igneous rock that forms from magma cooled below Earth's surface. Make a claim about why granite would have larger crystals than igneous rocks formed from lava cooled above Earth's surface. Support your claim with evidence and explain your reasoning.



SC.7.N.1.1 Define a problem from the seventh grade curriculum, use appropriate reference materials to support scientific understanding, plan and carry out scientific investigation of various types, such as systematic observations or experiments, identify variables, collect and organize data, interpret data in charts, tables, and graphics, analyze information, make predictions, and defend conclusions.

S.T.E.M. ENGINEERING & TECHNOLOGY

Analyzing Technology

Skills
Identify risks
Identify benefits
✓ Evaluate cost of technology
✓ Evaluate environmental impact
✓ Propose improvements
Propose risk reduction
✓ Compare technology
✓ Communicate results

Objectives
Analyze the life cycle of an aluminum can.
Analyze the life cycle of a glass bottle.
Evaluate the cost of recycling versus disposal of technology.
Analyze the environmental impact of technology.

Analyzing the Life Cycles of Aluminum and Glass

A life cycle analysis is a way to evaluate the real cost of a product. The analysis considers how much money an item costs to make. It also examines how making the product affects the economy and the environment through the life of the product. Engineers, scientists, and technologists use this information to improve processes and to compare products.

Costs of Production

Have you ever wondered where an aluminum soda can comes from? Have you wondered where the can goes when you are done with it? If so, you have started a life cycle analysis by asking the right questions. Aluminum is a metal found in a type of rock called *bauxite*. To get aluminum, first bauxite must be mined. The mined ore is then shipped to a processing plant. There, the bauxite is melted to get aluminum in a process called *smelting*. After smelting, the aluminum is processed. It may be shaped into bicycle parts or rolled into sheets to make cans. Every step in the production involves both financial costs and environmental costs that must be considered in a life cycle analysis.

Many bicycles are made of aluminum because it is lightweight and strong.



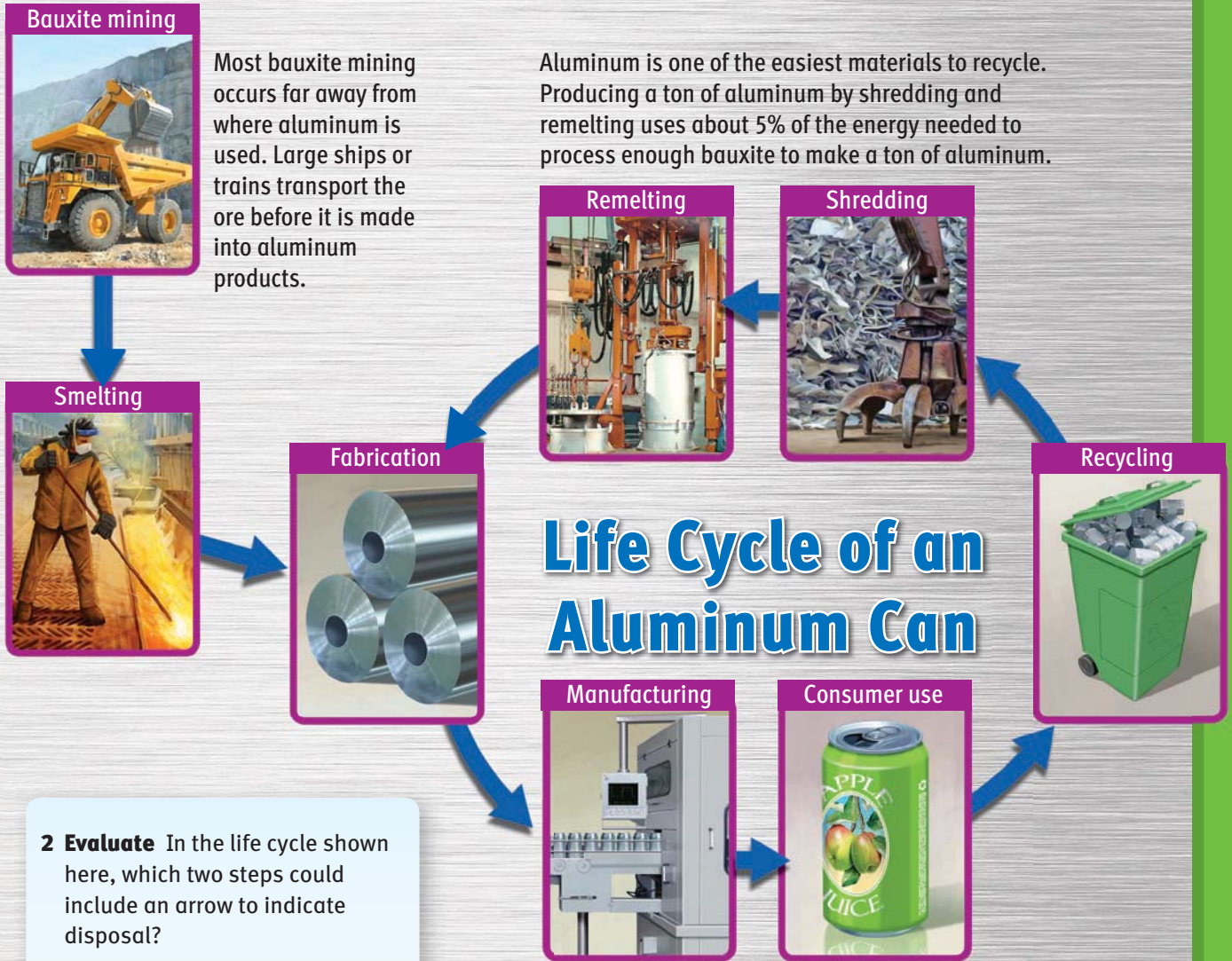
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Costs of Disposal

After an aluminum can is used it can travel either to a landfill or to a recycling plant. The process of recycling an aluminum can does require the use of some energy. However, the financial and environmental costs of disposing of a can and mining ore are much greater than the cost of recycling a can. Additionally, smelting bauxite produces harmful wastes. A life cycle analysis of an aluminum can must include the cost and environmental effects of mining, smelting, and disposing of the aluminum can.

1 Claims • Evidence • Reasoning Make a claim about which steps are no longer part of a can's life cycle after the can is recycled. Summarize evidence to support the claim and explain your reasoning.



2 Evaluate In the life cycle shown here, which two steps could include an arrow to indicate disposal?

You Try It!

Now it's your turn to analyze the life cycle of a product.

You Try It!

Now, apply what you have learned about the life cycle of aluminum to analyze the life cycle of a glass bottle. Glass is made by melting silica from sand or from mineral deposits mined from the Earth. A kiln heats the silica until it melts to form a red-hot gob. Then, the glass is shaped and cooled to form useful items.

① Evaluate Cost of Technology

As a group, discuss the steps that would be involved in making a glass bottle. List the steps in the space below. Start with mining and end at a landfill. Include as many steps in the process as you can think of. Beside each step, tell whether there would be financial costs, environmental costs, or both.

Life Cycle of a Glass Bottle

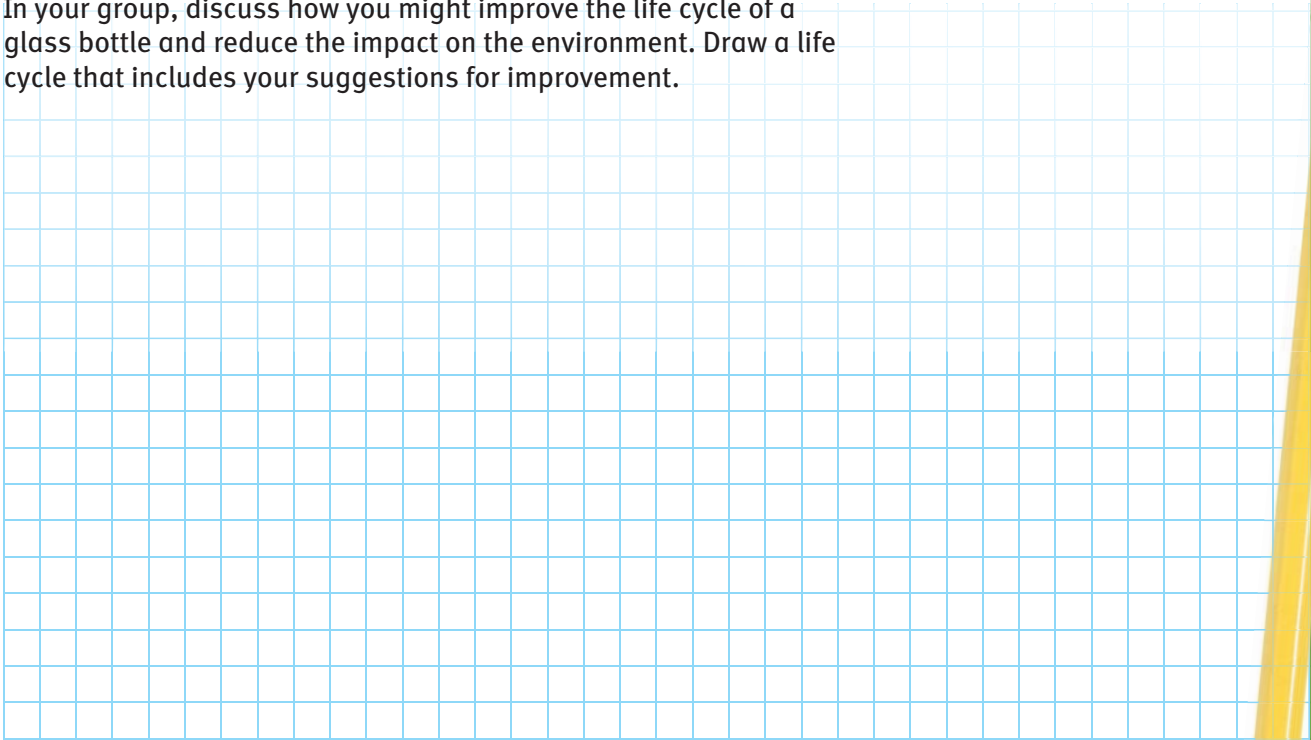
② Evaluate Environmental Impact

Use the table below to indicate which of the steps listed above would have environmental costs, and what type of cost would be involved. A step can appear in more than one column.

<i>Cause pollution</i>	<i>Consume energy</i>	<i>Damage habitat</i>

3 Propose Improvements

In your group, discuss how you might improve the life cycle of a glass bottle and reduce the impact on the environment. Draw a life cycle that includes your suggestions for improvement.

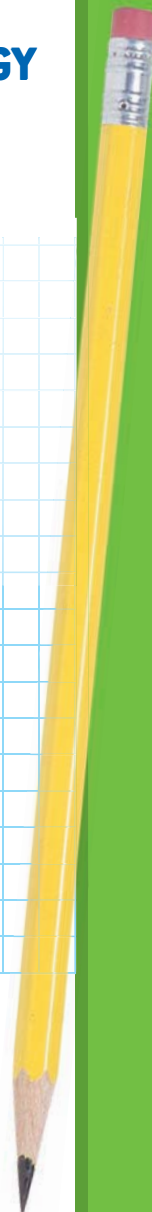


4 Compare Technology

Claims • Evidence • Reasoning How does your improved process decrease the environmental effects of making and using glass bottles? Provide evidence to support your claim and explain your reasoning.

5 Communicate Results

Imagine that you are an accountant for a company that produces glass bottles. In the space below, write an argument for using recycled glass that is based on financial savings for your company.



Earth's Layers

ESSENTIAL QUESTION

What are Earth's layers?

By the end of this lesson, you should be able to identify Earth's compositional and physical layers and describe their properties.

If you could dig below this canyon, you would discover that Earth is made up of different layers below its surface.



SC.7.E.6.1 Describe the layers of the solid Earth, including the lithosphere, the hot convecting mantle, and the dense metallic liquid and solid cores.

SC.7.E.6.7 Recognize that heat flow and movement of material within Earth causes earthquakes and volcanic eruptions, and creates mountains and ocean basins.

Lesson Labs

Quick Labs

- Tectonic Ice Cubes
- Layers of Earth

S.T.E.M. Lab

- Models of Earth

Engage Your Brain

1 Predict Check T or F to show whether you think each statement is true or false.

- | T | F | |
|--------------------------|--------------------------|---|
| <input type="checkbox"/> | <input type="checkbox"/> | The outermost layer of solid Earth is sometimes called the crust. |
| <input type="checkbox"/> | <input type="checkbox"/> | The crust is the densest layer. |
| <input type="checkbox"/> | <input type="checkbox"/> | The mantle is the layer between the crust and the core. |
| <input type="checkbox"/> | <input type="checkbox"/> | Earth's core is divided into five parts. |

2 Describe If you were asked to describe this apple, how many layers would you say it has? How would you describe the layers?



ACTIVE READING

3 Synthesize You can often define an unknown word if you know the meaning of its word parts. Use the word parts and sentence below to make an educated guess about the meaning of the word *mesosphere*.

Word part	Meaning
<i>meso-</i>	middle
<i>-sphere</i>	ball

Example sentence

The mesosphere is more than 2,000 km thick.

Mesosphere:

Vocabulary Terms

- crust
- mantle
- convection
- core
- lithosphere
- asthenosphere
- mesosphere

4 Apply As you learn the definition of each vocabulary term in this lesson, create your own definition or sketch to help you remember the meaning of the term.

Peeling the Layers

What is inside Earth?

If you tried to dig to the center of Earth, what do you think you would find? Would Earth be solid or hollow? Would it be made of the same material throughout? Actually, Earth is made of several layers. The materials that make up each layer have characteristic properties that vary from layer to layer. Scientists think about Earth's layers in two ways—in terms of their chemical composition and in terms of their physical properties.

i Think Outside the Book

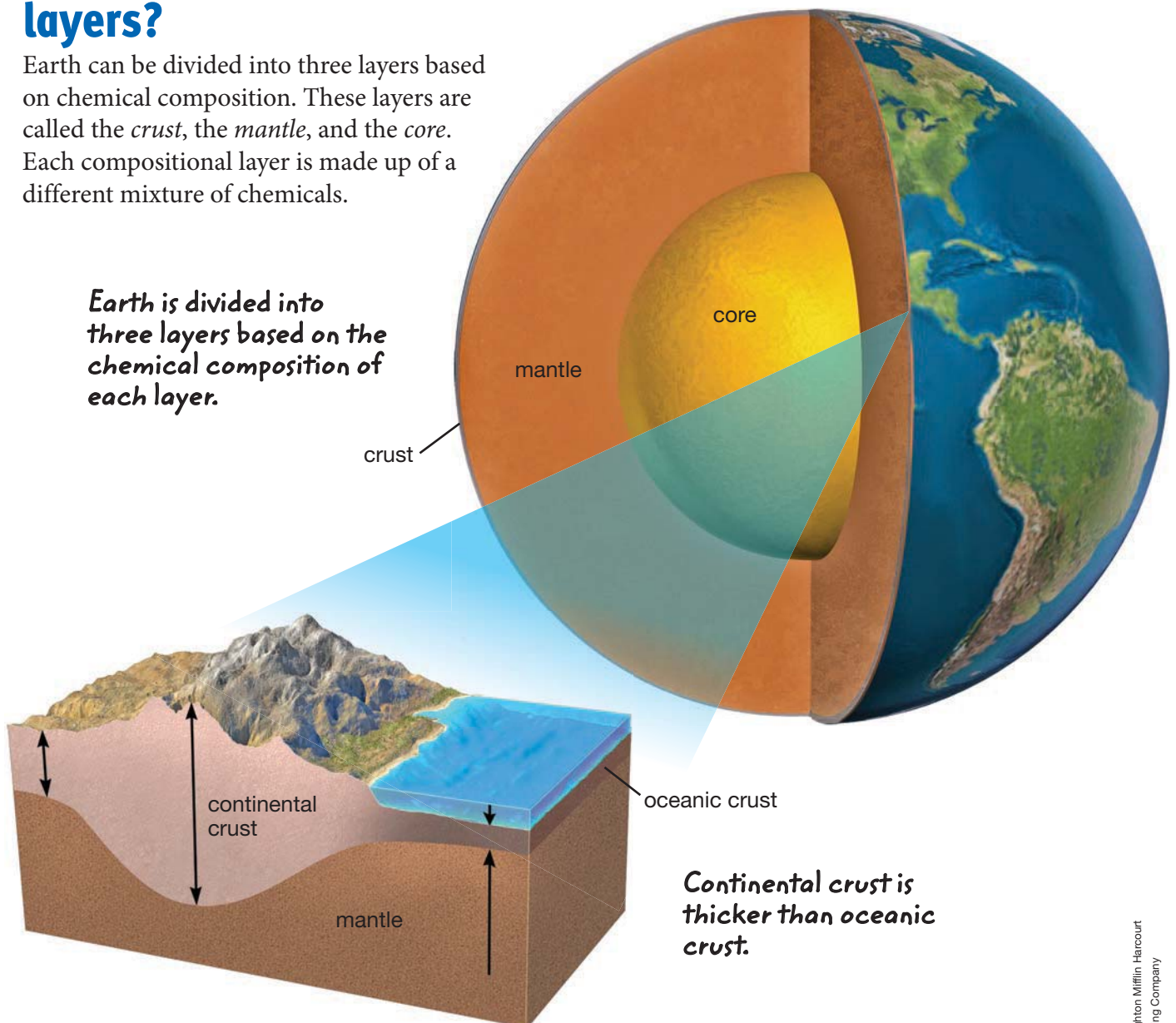
5 Claims • Evidence • Reasoning

Make a claim about why scientists might have two ways for thinking about Earth's layers. Summarize evidence to support the claim and explain your reasoning.

What are Earth's compositional layers?

Earth can be divided into three layers based on chemical composition. These layers are called the *crust*, the *mantle*, and the *core*. Each compositional layer is made up of a different mixture of chemicals.

Earth is divided into three layers based on the chemical composition of each layer.





Crust

The outermost solid layer of Earth is the **crust**. There are two types of crust—continental and oceanic. Both types are made mainly of the elements oxygen, silicon, and aluminum. However, the denser oceanic crust has almost twice as much iron, calcium, and magnesium. These elements form minerals that are denser than those in the continental crust.

ACTIVE READING

6 Identify List the compositional layers in order of most dense to least dense.

Mantle

The **mantle** is located between the core and the crust. It is a region of hot, slow-flowing, solid rock. When convection takes place in the mantle, cooler rock sinks and warmer rock rises. **Convection** is the movement of matter that results from differences in density caused by variations in temperature. Scientists can learn about the mantle by observing mantle rock that has risen to Earth's surface. The mantle is denser than the crust. It contains more magnesium and less aluminum and silicon than the crust does.

Core

The **core** extends from below the mantle to the center of Earth. Scientists think that the core is made mostly of iron and some nickel. Scientists also think that it contains much less oxygen, silicon, aluminum, and magnesium than the mantle does. The core is the densest layer. It makes up about one-third of Earth's mass.

ACTIVE READING

7 Identify What element makes up most of Earth's core?

What are Earth's physical layers?

Earth can also be divided into layers based on physical properties. The properties considered include whether the layer is solid or liquid, and how the layer moves or transmits waves. The five physical layers are the *lithosphere*, *asthenosphere*, *mesosphere*, *outer core*, and *inner core*.

ACTIVE READING

8 Label Write the names of the compositional layers shown below in the spaces provided.

Lithosphere

The outermost, rigid layer of Earth is the **lithosphere**. The lithosphere is made of two parts—the crust and the rigid, upper part of the mantle. The lithosphere is divided into pieces called *tectonic plates*.

Asthenosphere

The **asthenosphere** is a layer of weak or soft mantle that is made of rock that flows slowly. Tectonic plates move on top of this layer.

Mesosphere

The strong, lower part of the mantle is called the **mesosphere**. Rock in the mesosphere flows more slowly than rock in the asthenosphere does.

Outer Core

The outer core is the liquid layer of Earth's core. It lies beneath the mantle and surrounds the inner core.

Inner Core

The inner core is the solid, dense center of our planet that extends from the bottom of the outer core to the center of Earth, which is about 6,380 km beneath the surface.

Visualize It!

9 Claims • Evidence • Reasoning

Make a claim about which of Earth's compositional layers make up the lithosphere. Summarize evidence to support the claim and explain your reasoning.

A

B

C

Do the Math

Sample Problem

Here's an example of how to find the percentage thickness of the core that is the outer core.

Physical	Compositional
Continental lithosphere (150 km)	Continental crust (50 km)
Asthenosphere (250 km)	Mantle (2,900 km)
Mesosphere (2,550 km)	
Outer core (2,200 km)	Core (3,430 km)
Inner core (1,230 km)	

Identify

- A.** What do you know?
core = 3,430 km outer core = 2,200 km
- B.** What do you want to find out?
Percentage of core that is outer core

Plan

- C.** Write the formula:
Percentage (%) of core that is outer core =
- $$\left(\frac{\text{thickness of outer core}}{\text{thickness of core}} \right) \times 100\%$$
- D.** Substitute into the formula:
 $\% = \frac{(2,200)}{(3,430)} \times 100\%$

Solve

- E.** Calculate and simplify:
 $\% = 0.6414 \times 100\% = 64.14\%$

Answer: 64.14%

Do the Math

You Try It

- 10 Calculate** What percentage thickness of the continental lithosphere is continental crust?

Identify

- A.** What do you know?
- B.** What do you want to find out?

Plan

- C.** Write the formula:

- D.** Substitute into the formula:

Solve

- E.** Calculate and simplify:

Answer:

Visual Summary

To complete this summary, fill in the blanks with the correct word or phrase. You can use this page to review the main concepts of the lesson.

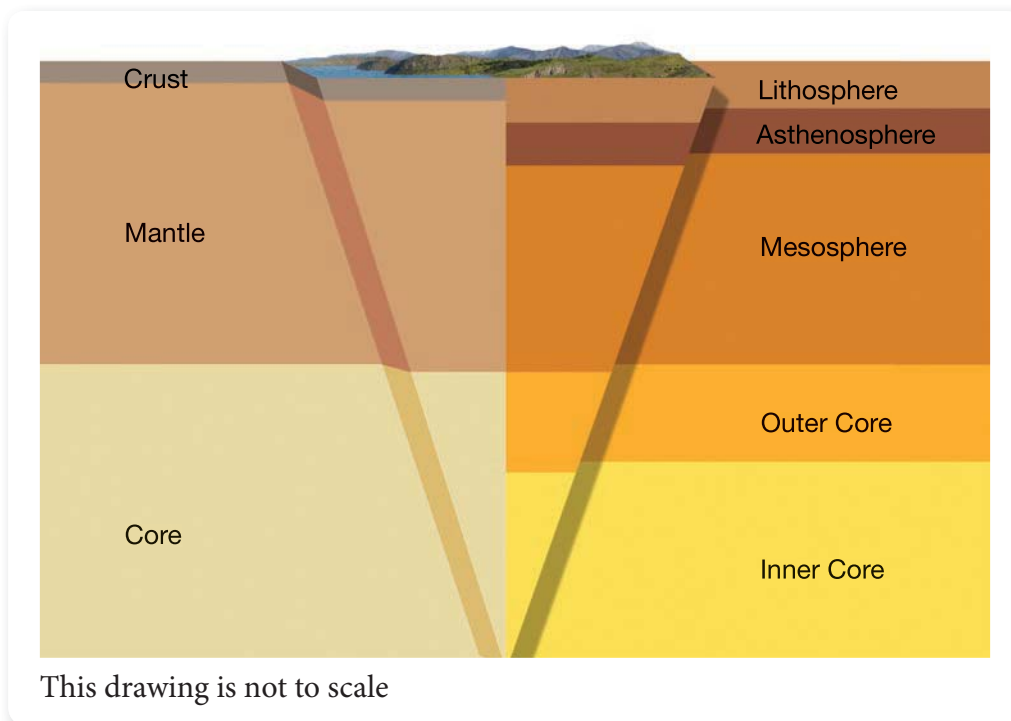
Earth is divided into three compositional layers.

- 11 The outermost compositional layer of the Earth is the _____.
- 12 The _____ is denser than the crust and contains more magnesium.

Earth is divided into five physical layers.

- 13 The _____ is divided into pieces called tectonic plates.
- 14 The _____ core is the liquid layer of Earth's core.

Earth's Layers



15 Claims • Evidence • Reasoning Make a claim about which physical layers correspond to which compositional layers. Give evidence to support the claim and explain your reasoning.

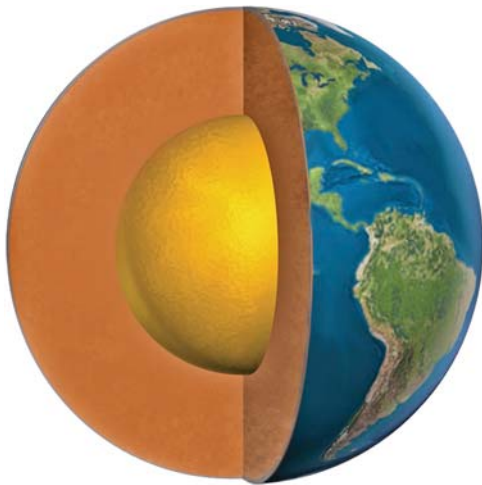
Vocabulary

Fill in the blank with the term that best completes the following sentence.

- 1 The _____ is a region of hot, slow-flowing, solid rock between the core and the crust.
- 2 The _____ is the densest compositional layer and makes up one-third of Earth's mass.
- 3 The _____ is the outermost, rigid physical layer of Earth.

Key Concepts

Use this diagram to answer the following questions.



4 Identify Which model of Earth's interior does this image show?

5 Identify Which of these layers is made mostly of iron and nickel?

6 Compare Explain the differences between the inner core and the outer core.

Critical Thinking

7 Compare Explain the difference between the lithosphere and the crust.

8 Claims • Evidence • Reasoning Scientists find dense rock on Earth's surface that is made of magnesium and smaller amounts of aluminum and silicon. Make a claim about which layer of Earth this rock might help scientists study. Summarize evidence to support the claim and explain your reasoning.

9 Apply In a model of Earth's layers that is determined by physical properties, how might the atmosphere be classified? Would it be part of the lithosphere, or a separate layer? Explain your answer.

Plate Tectonics

ESSENTIAL QUESTION

What is plate tectonics?

By the end of this lesson, you should be able to explain the theory of plate tectonics, to describe how tectonic plates move, and to identify geologic events that occur because of tectonic plate movement.



SC.7.E.6.1 Describe the layers of the solid Earth, including the lithosphere, the hot convecting mantle, and the dense metallic liquid and solid cores.

SC.7.E.6.2 Identify the patterns within the rock cycle and relate them to surface events (weathering and erosion) and sub-surface events (plate tectonics and mountain building). **SC.7.E.6.5** Explore the scientific theory of plate tectonics by describing how the movement of Earth's crustal plates causes both slow and rapid changes in Earth's surface, including volcanic eruptions, earthquakes, and mountain building. **SC.7.E.6.7** Recognize that heat flow and movement of material within Earth causes earthquakes and volcanic eruptions, and creates mountains and ocean basins.

The San Andreas Fault is located where two tectonic plates slide past each other.

The course of this river has been shifted as a result of tectonic plate motion.

Lesson Labs

Quick Labs

- Reconstructing Land Masses
- What Happens When Objects Collide?
- Mantle Convection

Exploration Lab

- Seafloor Spreading



Engage Your Brain

1 Identify Check T or F to show whether you think each statement is true or false.

- | T | F | |
|--------------------------|--------------------------|--|
| <input type="checkbox"/> | <input type="checkbox"/> | Earth's surface is all one piece. |
| <input type="checkbox"/> | <input type="checkbox"/> | Scientists think the continents once formed a single landmass. |
| <input type="checkbox"/> | <input type="checkbox"/> | The sea floor is smooth and level. |
| <input type="checkbox"/> | <input type="checkbox"/> | All tectonic plates are the same. |

2 Predict Imagine that ice cubes are floating in a large bowl of punch. If there are enough cubes, they will cover the surface of the punch and bump into one another. Parts of the cubes will be below the surface of the punch and will displace the punch. Will some cubes displace more punch than others? Explain your answer.

ACTIVE READING

3 Apply Many scientific words, such as *divergent* and *convergent*, also have everyday meanings or are related to words with everyday meanings. Use context clues to write your own definition for each underlined word.

Example sentence

They argued about the issue because their opinions about it were divergent.

divergent:

Example sentence

The two rivers converged near the town.

convergent:

Vocabulary Terms

- Pangaea
- convergent boundary
- sea-floor spreading
- divergent boundary
- plate tectonics
- transform boundary
- tectonic plates
- convection

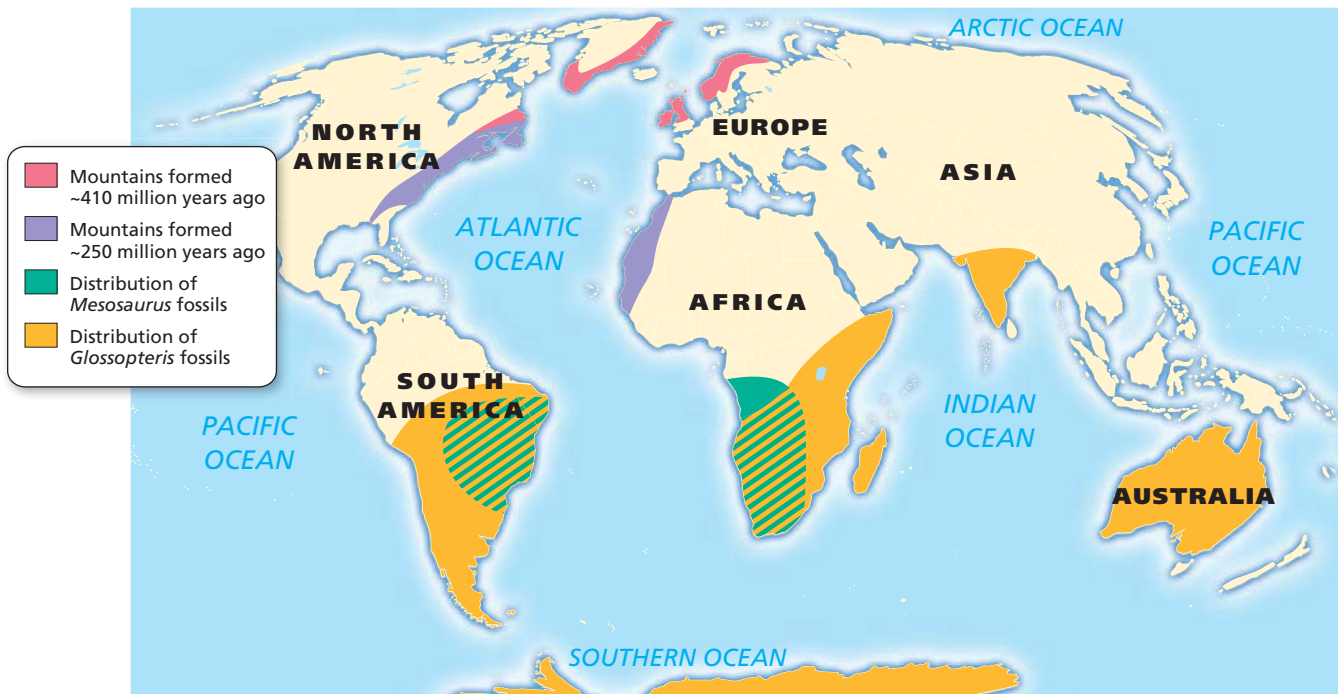
4 Identify This list contains key terms you'll learn in this lesson. As you read, underline the definition of each term.

Puzzling Evidence

What evidence suggests that continents move?

Have you ever looked at a map and noticed that the continents look like they could fit together like puzzle pieces? In the late 1800s, Alfred Wegener proposed his hypothesis of continental drift. He proposed that the continents once formed a single landmass, broke up, and drifted. This idea is supported by several lines of evidence. For example, fossils of the same species are found on continents on different sides of the Atlantic Ocean. These species could not have crossed the ocean. The hypothesis is also supported by the locations of mountain ranges and rock formations and by evidence of the same ancient climatic conditions on several continents.

Geologic evidence supports the hypothesis of continental drift.



Visualize It!

5 Summarize Using the map and its key, complete the table to describe evidence that indicates each continent pair was once joined.

	Fossil evidence	Mountain evidence
South America and Africa		
North America and Europe		

What is Pangaea?

ACTIVE READING

6 Identify As you read, underline the description of how North America formed from Pangaea.

Using evidence from many scientific fields, scientists can construct a picture of continental change throughout time. Scientists think that about 245 million years ago, the continents were joined in a single large landmass they call **Pangaea** (pan•JEE•uh). As the continents collided to form Pangaea, mountains formed. A single, large ocean called Panthalassa surrounded Pangaea.

About 200 million years ago, a large rift formed and Pangaea began to break into two continents—*Laurasia* and *Gondwana*. Then, Laurasia began to drift northward and rotate slowly, and a new rift formed. This rift separated Laurasia into the continents of North America and Eurasia. The rift eventually formed the North Atlantic Ocean. At the same time, Gondwana also broke into two continents. One continent contained land that is now the continents of South America and Africa. The other continent contained land that is now Antarctica, Australia, and India.

About 150 million years ago, a rift between Africa and South America opened to form the South Atlantic Ocean. India, Australia, and Antarctica also began to separate from each other. As India broke away from Australia and Antarctica, it started moving northward, toward Eurasia.

As India and the continents moved into their present positions, new oceans formed while others disappeared. In some cases, continents collided with other continents. About 50 million years ago, India collided with Eurasia, and the Himalaya Mountains began to form. Mountain ranges form as a result of these collisions, because a collision welds new crust onto the continents and uplifts some of the land.

The Breakup of Pangaea



245 million years ago



200 million years ago



65 million years ago



3 million years ago

What discoveries support the idea of continental drift?

Wegener's ideas of continental drift were pushed aside for many years because scientists could not determine how continents moved. Then, in the mid-1900s, scientists began mapping the sea floor. They expected the floor to be smooth and level. Instead, they found huge under-water mountain ranges called *mid-ocean ridges*. The discovery of mid-ocean ridges eventually led to the theory of plate tectonics, which built on some of Wegener's ideas.

○ Age and Magnetic Properties of the Sea Floor

Scientists learned that the mid-ocean ridges form along cracks in the crust. Rock samples from the sea floor revealed that the youngest rock is closest to the ridge, while the oldest rock is farthest away. The samples also showed that even the oldest ocean crust is young compared to continental crust. Scientists also discovered that sea-floor rock contains magnetic patterns. These patterns form mirror images on either side of a mid-ocean ridge.

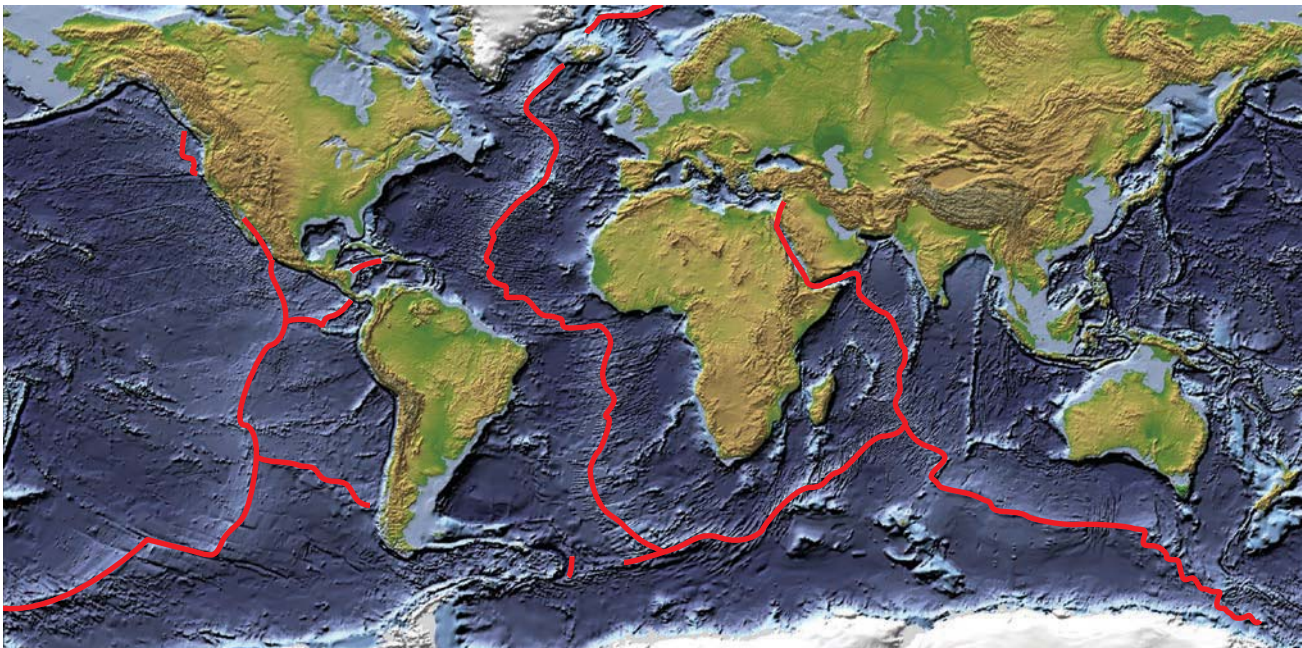
○ Sea-Floor Spreading

To explain the age and magnetic patterns of sea-floor rocks, scientists proposed a process called **sea-floor spreading**. In this process, molten rock from inside Earth rises through the cracks in the ridges, cools, and forms new oceanic crust. The old crust breaks along the mid-point of the ridge and the two pieces of crust move away in opposite directions from each other. In this way, the sea floor slowly spreads apart. As the sea floor moves, so do the continents on the same piece of crust.

7 Claims • Evidence • Reasoning

Make a claim about why many scientists would not accept the hypothesis of continental drift. Give evidence to support the claim and explain your reasoning.

This map shows where mid-ocean ridges are located.



Ocean Trenches

If the sea floor has been spreading for millions of years, why is Earth not getting larger? Scientists discovered the answer when they found huge trenches, like deep canyons, in the sea floor. At these sites, dense oceanic crust is sinking into the asthenosphere as shown in the diagram below. Older crust is being destroyed at the same rate new crust is forming. Thus, Earth remains the same size.

With this new information about the sea floor, sea-floor spreading, and ocean trenches, scientists could begin to understand how continents were able to move.

ACTIVE READING

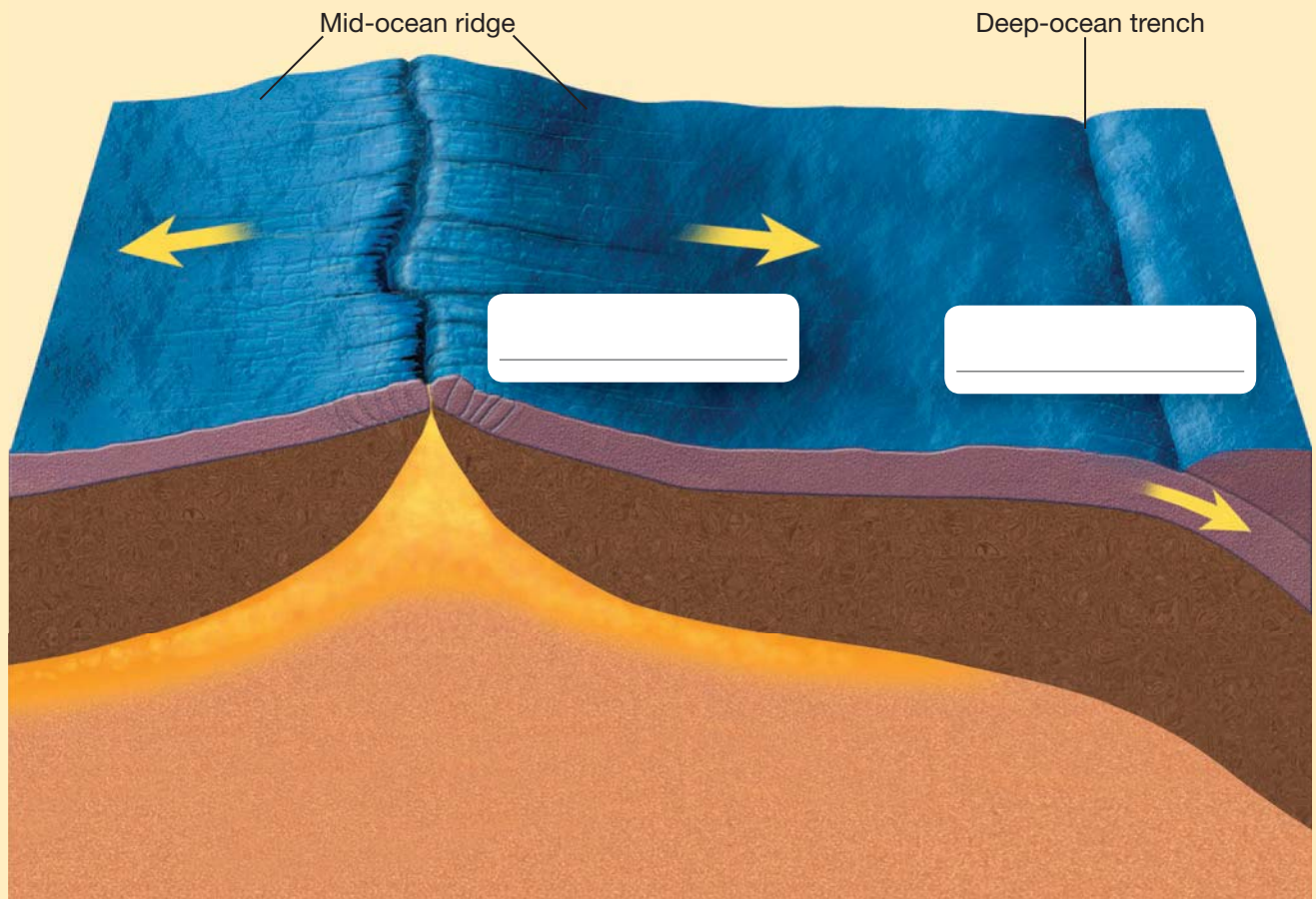
8 Claims • Evidence • Reasoning

Make a claim about why Earth isn't getting larger if the sea floor is spreading. Summarize evidence to support the claim and explain your reasoning.

Visualize It!

9 Provide Label the youngest rock and the oldest rock on this diagram of sea-floor spreading.

Sea-floor spreading takes place at mid-ocean ridges.



A Giant Jigsaw

Think Outside the Book

10 Apply Imagine that the theory of plate tectonics has just been proposed. Design a magazine ad for the theory.

What is the theory of plate tectonics?

As scientists' understanding of continental drift, mid-ocean ridges, and sea-floor spreading grew, scientists formed a theory to explain these processes and features. **Plate tectonics** describes large-scale movements of Earth's lithosphere, which is made up of the crust and the rigid, upper part of the mantle. Plate tectonics explains how and why features in Earth's crust form and continents move.

What is a tectonic plate?

The lithosphere is divided into pieces called **tectonic plates**. These plates move around on top of the asthenosphere. The plates are moving in different directions and at different speeds. Each tectonic plate fits together with the plates that surround it. The continents are located on tectonic plates and move around with them. The major tectonic plates include the Pacific, North American, Nazca, South American, African, Australian, Eurasian, Indian, and Antarctic plates. Not all tectonic plates are the same. The South American plate has an entire continent on it and has oceanic crust. The Nazca plate has only oceanic crust.

Tectonic plates cover the surface of the asthenosphere. They vary in size, shape, and thickness. Thick tectonic plates, such as those with continents, displace more asthenosphere than thin oceanic plates do. But, oceanic plates are much more dense than continental plates are.

ACTIVE READING

11 Identify As you read, underline the definition of *tectonic plates*.

The Andes Mountains formed where the South American plate and Nazca plate meet.



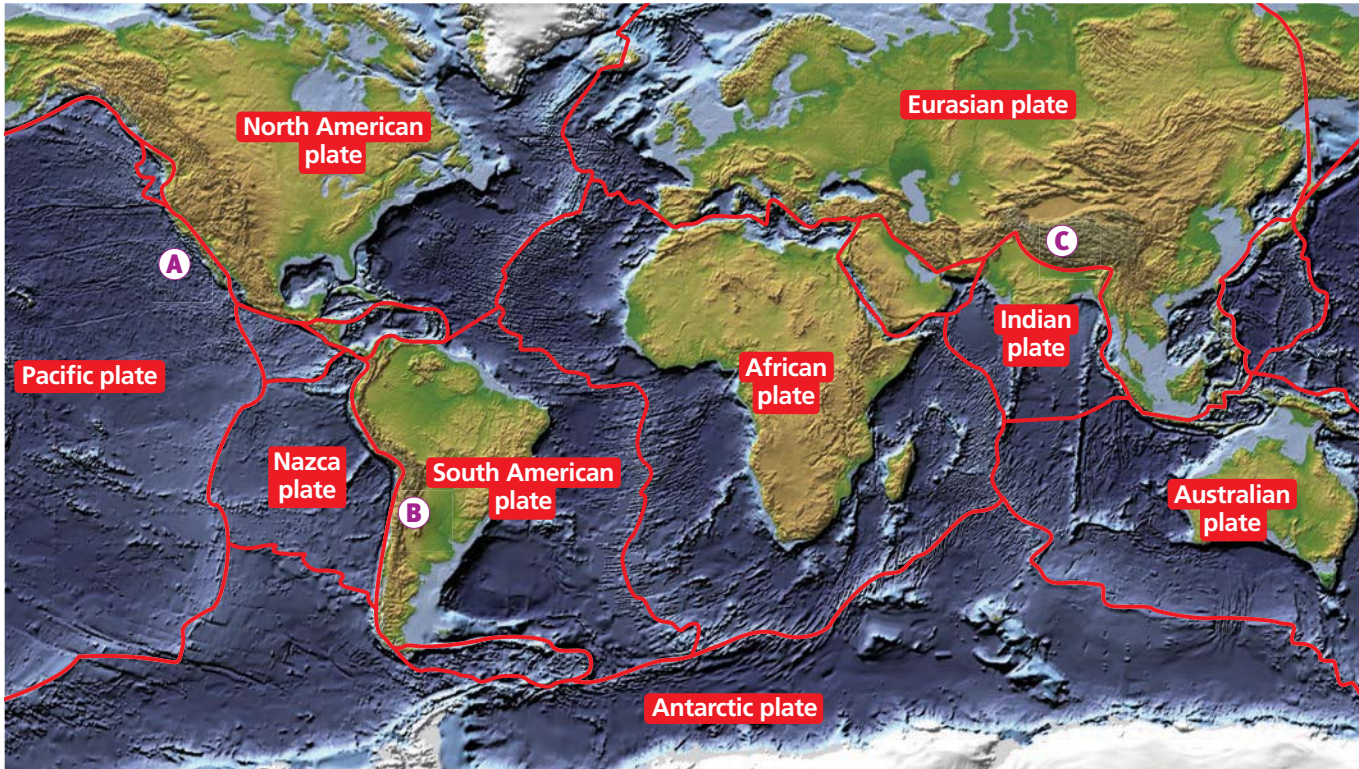
© Emil von Manteuffel/Corbis Images/Getty Images

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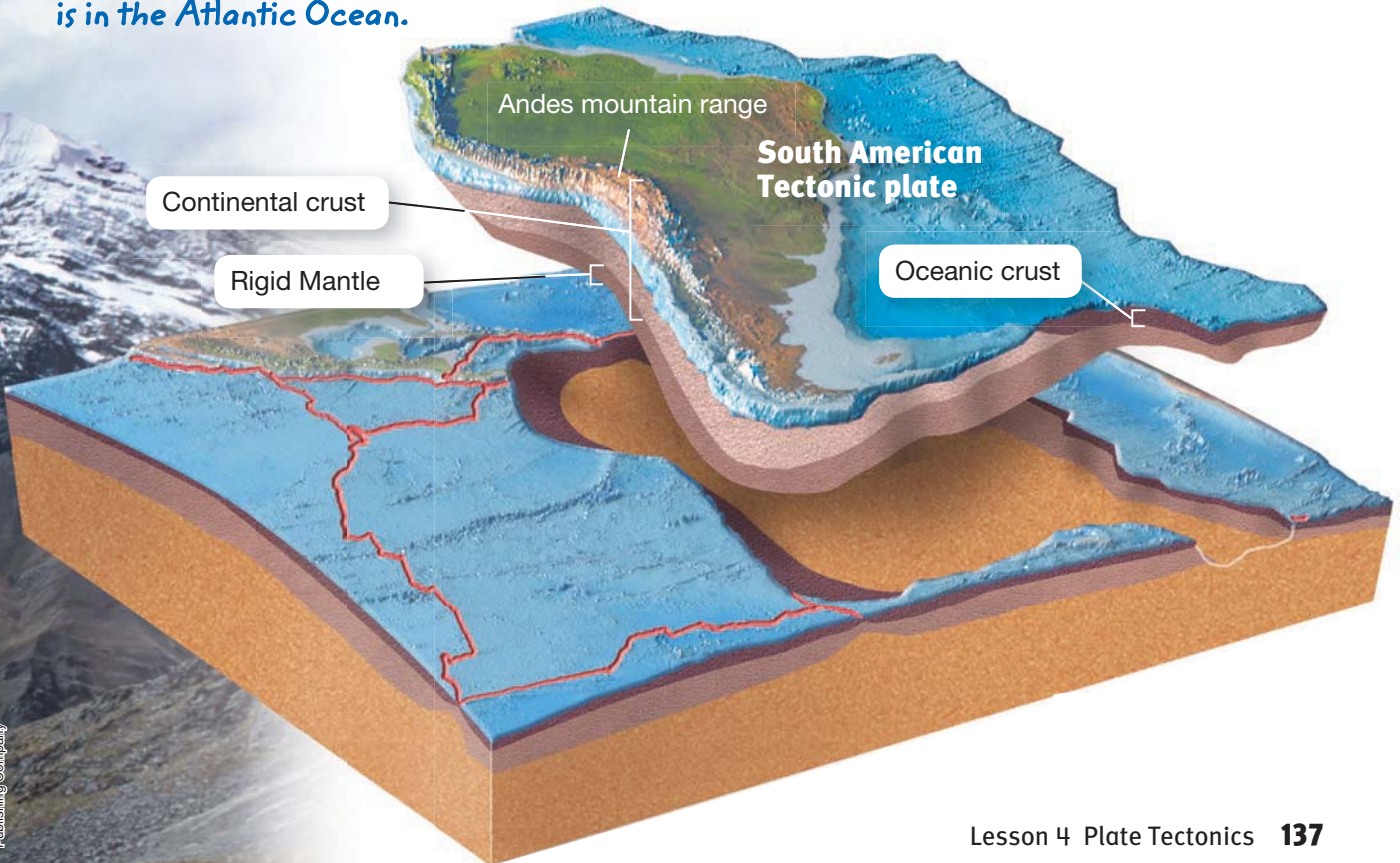
Visualize It!

12 Locate Which letter marks where the Andes Mountains are located on the map of tectonic plates, A, B, or C? _____

The tectonic plates fit together like the pieces of a jigsaw puzzle.



The thickest part of the South American plate is the continental crust. The thinnest part of this plate is in the Atlantic Ocean.



Boundaries

What are the three types of plate boundaries?

The most dramatic changes in Earth's crust occur along plate boundaries. Plate boundaries may be on the ocean floor, around the edges of continents, or even within continents. There are three types of plate boundaries: divergent boundaries, convergent boundaries, and transform boundaries. Each type of plate boundary is associated with characteristic landforms.

ACTIVE READING

13 Identify As you read, underline the locations where plate boundaries may be found.

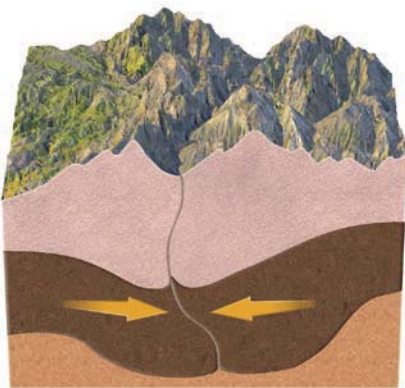
Convergent Boundaries

Convergent boundaries form where two plates collide. Three types of collisions can happen at convergent boundaries. When two tectonic plates of continental lithosphere collide, they buckle and thicken, which pushes some of the continental crust upward. When a plate of oceanic lithosphere collides with a plate of continental lithosphere, the denser oceanic lithosphere sinks into the asthenosphere. Boundaries where one plate sinks beneath another plate are called subduction zones. When two tectonic plates of oceanic lithosphere collide, one of the plates subducts, or sinks, under the other plate.



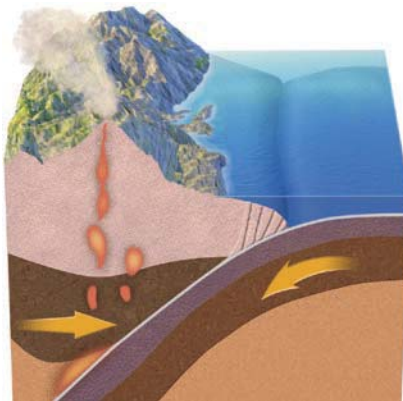
14 Claims • Evidence • Reasoning

Make a claim about why the denser plate subducts in a collision. Support the claim with evidence and explain your reasoning.



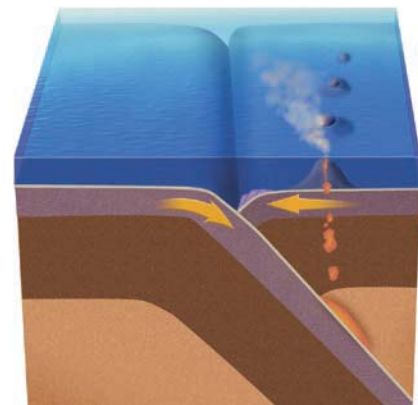
Continent-Continent Collisions

When two plates of continental lithosphere collide, they buckle and thicken. This causes mountains to form.



Continent-Ocean Collisions

When a plate of oceanic lithosphere collides with a plate of continental lithosphere, the oceanic lithosphere subducts because it is denser.



Ocean-Ocean Collisions

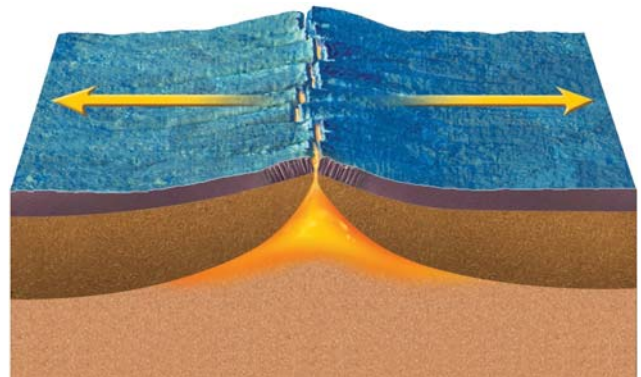
When two plates of oceanic lithosphere collide, the older, denser plate subducts under the other plate.

Divergent Boundaries

At a **divergent boundary**, two plates move away from each other. This separation allows the asthenosphere to rise toward the surface and partially melt. This melting creates magma, which erupts as lava. The lava cools and hardens to form new rock on the ocean floor.

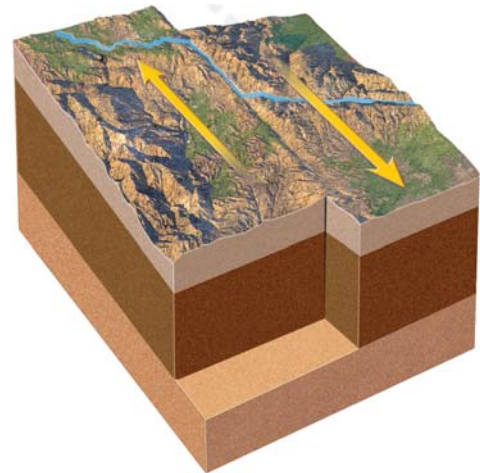
As the crust and the upper part of the asthenosphere cool and become rigid, they form new lithosphere. This lithosphere is thin, warm, and light. This warm, light rock sits higher than the surrounding sea floor because it is less dense. It forms mid-ocean ridges. Most divergent boundaries are located on the ocean floor. However, rift valleys may also form where continents are separated by plate movement.

At divergent boundaries, plates separate.



Transform Boundaries

A boundary at which two plates move past each other horizontally is called a **transform boundary**. However, the plate edges do not slide along smoothly. Instead, they scrape against each other in a series of sudden slippages of crustal rock that are felt as earthquakes. Unlike other types of boundaries, transform boundaries generally do not produce magma. The San Andreas Fault in California is a major transform boundary between the North American plate and the Pacific plate. Transform motion also occurs at divergent boundaries. Short segments of mid-ocean ridges are connected by transform faults called fracture zones.



At transform boundaries, plates slide past each other horizontally.

ACTIVE READING

15 Claims • Evidence • Reasoning How are transform boundaries different from convergent and divergent boundaries? Provide evidence to support the claim and explain your reasoning.

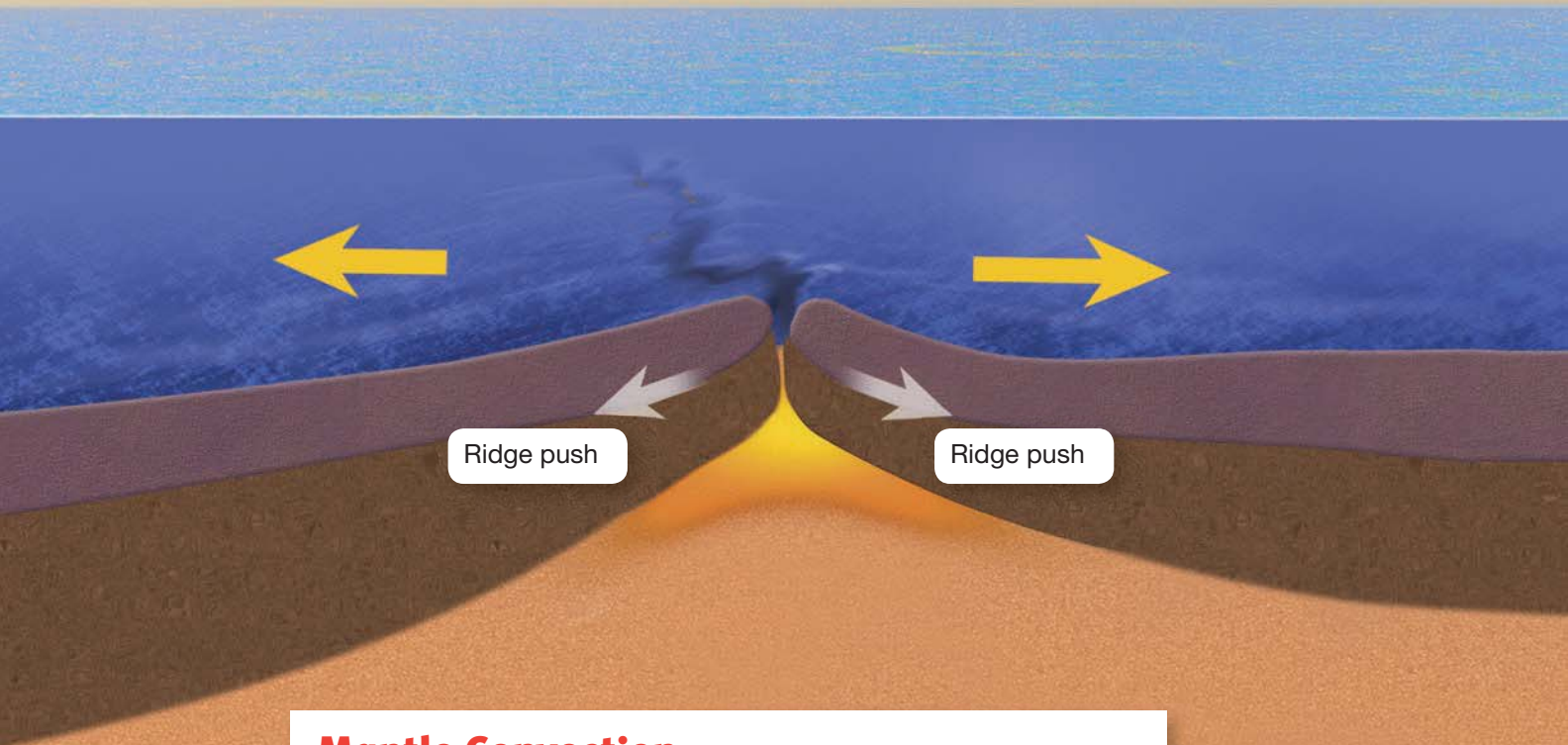
Hot Plates

What causes tectonic plates to move?

Scientists have proposed three mechanisms to explain how tectonic plates move over Earth's surface. Mantle convection drags plates along as mantle material moves beneath tectonic plates. Ridge push moves plates away from mid-ocean ridges as rock cools and becomes more dense. Slab pull tugs plates along as the dense edge of a plate sinks beneath Earth's surface.

ACTIVE READING

16 Identify As you read, underline three mechanisms scientists have proposed to explain plate motion.



Mantle Convection

As atoms in Earth's core and mantle undergo radioactive decay, energy is released as heat. Some parts of the mantle become hotter than others parts. The hot parts rise as the sinking of cooler, denser material pushes the heated material up. This kind of movement of material due to differences in density is called **convection**. It was thought that as the mantle convects, or moves, it would drag the overlying tectonic plates along with it. However, this hypothesis has been criticized by many scientists because it does not explain the huge amount of force that would be needed to move plates.

Ridge Push

Newly formed rock at a mid-ocean ridge is warm and less dense than older, adjacent rock. Because of its lower density, the new rock rests at a higher elevation than the older rock. The older rock slopes downward away from the ridge. As the newer, warmer rock cools, it also becomes more dense. These cooling and increasingly dense rocks respond to gravity by moving down the slope of the asthenosphere, away from the ridge. This force, called ridge push, pushes the rest of the plate away from the mid-ocean ridge.

Slab Pull

At subduction zones, a denser tectonic plate sinks, or subducts, beneath another, less dense plate. The leading edge of the subducting plate is colder and denser than the mantle. As it sinks, the leading edge of the plate pulls the rest of the plate with it. This process is called slab pull. In general, subducting plates move faster than other plates do. This evidence leads many scientists to think that slab pull may be the most important mechanism driving tectonic plate motion.



17 Compare Complete the chart with brief descriptions to compare and contrast mantle convection, ridge push, and slab pull.

<i>Mechanisms</i>		
<i>Mantle convection</i>	<i>Ridge push</i>	<i>Slab pull</i>

Visual Summary

Plate Tectonics

To complete this summary, fill in the blanks to complete the label or caption. You can use this page to review the main concepts of the lesson.

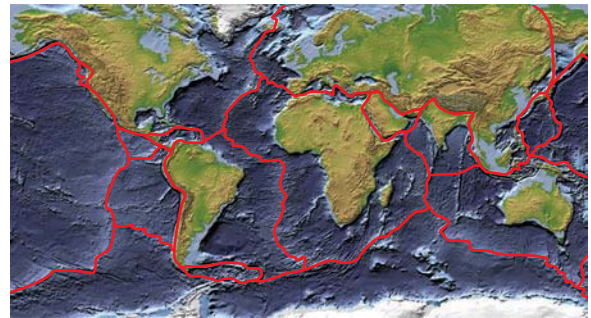
The continents were joined in a single landmass.

18 Scientists call the landmass _____



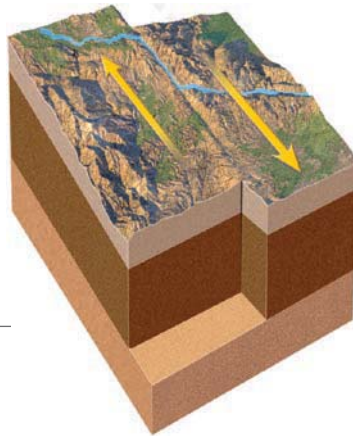
Tectonic plates differ in size and composition.

19 The United States lies on the _____ plate.



There are three types of plate boundaries: convergent, divergent, and transform.

20 This image shows a _____ boundary.



Three mechanisms may drive plate motion. These are mantle convection, slab pull, and ridge push.

21 The mechanism that scientists think is most important is _____



22 Synthesize How does the flow of energy as heat in Earth's interior contribute to the movement of tectonic plates? Make a claim about what would happen if Earth were not a convecting system. Use evidence to support your claim, and explain your reasoning.

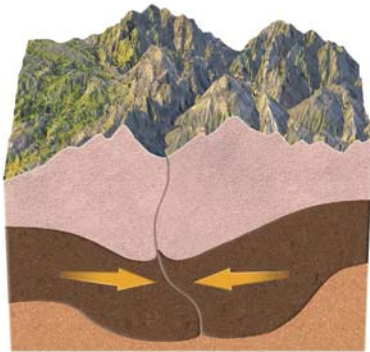
Vocabulary

Fill in the blanks with the term that best completes the following sentences.

- 1 The lithosphere is divided into pieces called _____
- 2 The theory that describes large-scale movements of Earth's lithosphere is called _____
- 3 The movement of material due to differences in density that are caused by differences in temperature is called _____

Key Concepts

Use this diagram to answer the following questions.



- 4 **Identify** What type of plate boundary is shown?

- 5 **Identify** Which types of lithosphere are colliding at this boundary?

- 6 **Identify** What landforms are likely to form at this boundary?

- 7 **Describe** How is continental lithosphere different from oceanic lithosphere?

- 8 **Compare** How are convergent boundaries different from divergent boundaries?

Critical Thinking

- 9 **Claims • Evidence • Reasoning** Make a claim about why cool rock material sinks when convection takes place in the mantle. Summarize evidence to support the claim and explain your reasoning.

- 10 **Defend** A friend says that Earth's continents are too large and massive to move. Explain to your friend why continents move. Defend your claim with evidence.



Estella Atekwana

GEOPHYSICIST

Dr. Estella Atekwana studies changes on Earth’s surface. Some of the changes may tell us how life on Earth developed. Others may help us to detect whether life exists somewhere else in the universe.

Some of Dr. Atekwana’s work takes her to Botswana and Zambia in Africa. There she is studying the formation of a new rift valley. Rift valleys are places where continents break apart. (For example, long ago a rift valley formed, and Africa broke apart from South America.) Studying this rift valley, Dr. Atekwana hopes to learn more about how new landmasses form. Further, the ground reveals the remains of plants and animals that once lived there. These remains can tell us

more about the climate that existed there millions of years ago.

Currently, Dr. Atekwana is doing brand new research in a new field of geology known as biogeophysics. She is looking at the effects that microorganisms have on rocks. She is using new technologies to study how rock changes after microorganisms have mixed with it. This research may one day help scientists detect evidence of life on other planets. Looking for the same geophysical changes in the rocks on Mars might be a way of detecting whether life ever existed on that planet. If the rocks show the same changes as the rocks on Earth, it could be because microorganisms once lived in them.

Dr. Atekwana’s research included this visit to Victoria Falls on the Zambezi River in Africa.



Social Studies Connection

Dr. Atekwana studies rift valleys—areas where the tectonic plates are pulling apart. Research to find out where else in the world scientists have located rift valleys.



(Clockwise from top left) The image Bank/Getty Images (top) Photo courtesy of Dr. Estella Atekwana

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JOB BOARD

Surveying and Mapping Technicians

What You'll Do: Help surveyors take measurements of outdoor areas. Technicians hold measuring tapes and adjust instruments, take notes, and make sketches.

Where You Might Work: Outdoors and indoors entering measurements into a computer.

Education: Some post-secondary education to obtain a license.

Other Job Requirements: Technicians must be able to visualize objects, distances, sizes, and shapes. They must be able to work with great care, precision, and accuracy because mistakes can be expensive. They must also be in good physical condition.



Geologist

What You'll Do: Study the history of Earth's crust. Geologists work in many different businesses. You may explore for minerals, oil, or gas. You may find and test ground water supplies. You may work with engineers to make sure ground is safe to build on.

Where You Might Work: In the field, where you collect samples, and in the office, where you analyze them. Geologists work in mines, on oil rigs, on the slopes of volcanoes, in quarries, and in paleontological digs.

Education: A four-year bachelor's degree in science.

Other Job Requirements: Geologists who work in the field must be in good physical condition. Most geologists do field training. Geologists need strong math skills, analytical skills, and computer skills. They also need to be able to work well with other members of a team.

Petroleum Technician

What You'll Do: Measure and record the conditions in oil or gas wells to find out whether samples contain oil and other minerals.

Where You Might Work: Outdoors, sometimes in remote locations and sometimes in your own town or city.

Education: An associate's degree or a certificate in applied science or science-related technology.

Other Job Requirements: You need to be able to take accurate measurements and keep track of many details.

Mountain Building

ESSENTIAL QUESTION

How do mountains form?

By the end of this lesson, you should be able to describe how the movement of Earth's tectonic plates causes mountain building.



SC.7.N.1.1 Define a problem from the seventh grade curriculum, use appropriate reference materials to support scientific understanding, plan and carry out scientific investigation of various types, such as systematic observations or experiments, identify variables, collect and organize data, interpret data in charts, tables, and graphics, analyze information, make predictions, and defend conclusions. **SC.7.E.6.5** Explore the scientific theory of plate tectonics by describing how the movement of Earth's crustal plates causes both slow and rapid changes in Earth's surface, including volcanic eruptions, earthquakes, and mountain building. **SC.7.E.6.7** Recognize that heat flow and movement of material within Earth causes earthquakes and volcanic eruptions, and creates mountains and ocean basins.

The highest peak in the Alps mountain range is Mont Blanc at just over 4,800 m tall.

Lesson Labs

Quick Labs

- Modeling Geologic Processes
- Modeling Strike-Slip Faults

Engage Your Brain

1 Predict Check T or F to show whether you think each statement is true or false.

- | T | F | |
|--------------------------|--------------------------|---|
| <input type="checkbox"/> | <input type="checkbox"/> | Mountains can originate from a level surface that is folded upward. |
| <input type="checkbox"/> | <input type="checkbox"/> | Rocks can be pulled apart by the movement of tectonic plates. |
| <input type="checkbox"/> | <input type="checkbox"/> | All mountains are created by volcanoes. |
| <input type="checkbox"/> | <input type="checkbox"/> | A mountain range can form only at the edge of a tectonic plate. |

Rocky Mountains

Appalachian Mountains

2 Hypothesize The Appalachian Mountains were once taller than the Rocky Mountains. What do you think happened to the mountains? Explain your reasoning.

ACTIVE READING

3 Compare The terms *compression* and *tension* have opposite meanings. Compare the two sentences below, then write your own definition for *compression* and *tension*.

Vocabulary	Sentence
compression	The stack of books on Jon's desk caused the bottom book to be flattened by <u>compression</u> .
tension	Keisha pulled the piece of string so hard, the <u>tension</u> caused the string to break.

compression:

tension:

Vocabulary Terms

- deformation
- folding
- fault
- shear stress
- tension
- compression

4 Apply As you learn the definition of each vocabulary term in this lesson, create your own definition or sketch to help you remember the meaning of the term.

Stressed Out

How can tectonic plate motion cause deformation?

The movement of tectonic plates places stress on rocks. A tectonic plate is a block of lithosphere that consists of crust and the rigid outermost part of the mantle. *Stress* is the amount of force per unit area that is placed on an object. Rocks can bend or break under stress. In addition, low temperatures make materials more brittle, or easily broken. High temperatures can allow rock to bend.

When a rock is placed under stress, it deforms, or changes shape. **Deformation** (dee•fohr•MAY•shuhn) is the process by which rocks change shape when under stress. Rock can bend if it is placed under high temperature and pressure for long periods of time. If the stress becomes too great, or is applied quickly, rock can break. When rocks bend, folds form. When rocks break, faults form.

ACTIVE READING

5 Identify As you read, list some objects near you that can bend or break from deformation.

By applying stress, the boy is causing the spaghetti to deform. Similarly, stress over a long period of time can cause rock to bend.

Like the spaghetti, stress over a short period of time or great amounts of stress can cause rock to break.



Visualize It!

6 Claims • Evidence • Reasoning Make a claim about how the same material might bend in one situation but break in another. Provide evidence to support the claim and explain your reasoning.



What are two kinds of folds?

Folded rock layers appear bent or buckled. **Folding** occurs when rock layers bend under stress. The bends are called *folds*. Scientists assume that all rock layers start out as horizontal layers deposited on top of each other over time. Sometimes, different layers of rocks can still be seen even after the rocks have been folded. When scientists see a fold, they know that deformation has happened. Two common types of folds are synclines and anticlines.

Think Outside the Book

7 Model Stack several sheets of paper together. Apply stress to the sides of the paper to create a model of a syncline and an anticline. Share your model with your teacher.

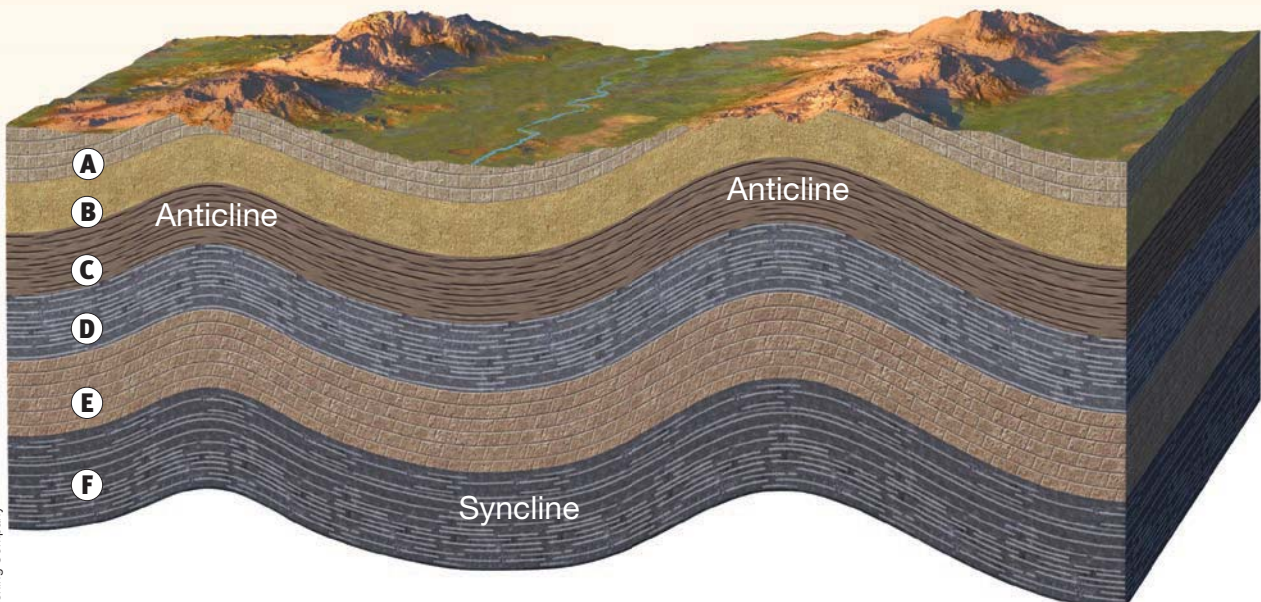
Synclines and Anticlines

Folds are classified based on the age of the rock layers. In a *syncline* (SIN•klyn), the youngest layers of rock are found at the core of a fold. The oldest layers are found on the outside of the fold. Synclines usually look like rock layers that are arched upward, like a bowl. In an *anticline* (AN•tih•klyn), the oldest layers of rock are found at the core of the fold. The youngest layers are found on the outside of the fold. Anticlines often look like rock layers that are arched downwards and high in the middle. Often, both types of folds will be visible in the same rock layers, as shown below.

The hinge is the middle point of the bend in a syncline or anticline.

Visualize It!

8 Claims • Evidence • Reasoning Make a claim about which rock layers are youngest and oldest. Summarize evidence to support the claim and explain your reasoning.



(t) ©Robert Harding Picture Library Ltd/Alamy

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Faulted

What are the three kinds of faults?

Rock can be under so much stress that it cannot bend and may break. The crack that forms when large blocks of rock break and move past each other is called a **fault**. The blocks of rock on either side of the fault are called *fault blocks*. The sudden movement of fault blocks can cause earthquakes.

Any time there is a fault in Earth's crust, rocks tend to move in predictable ways. Earth has three main kinds of faults: strike-slip faults, normal faults, and reverse faults. Scientists classify faults based on the way fault blocks move relative to each other. The location where two fault blocks meet is called the *fault plane*. A fault plane can be oriented horizontally, vertically, or at any angle in between. For any fault except a perfectly vertical fault, the block above the fault plane is called the *hanging wall*. The block below the fault plane is the *footwall*.

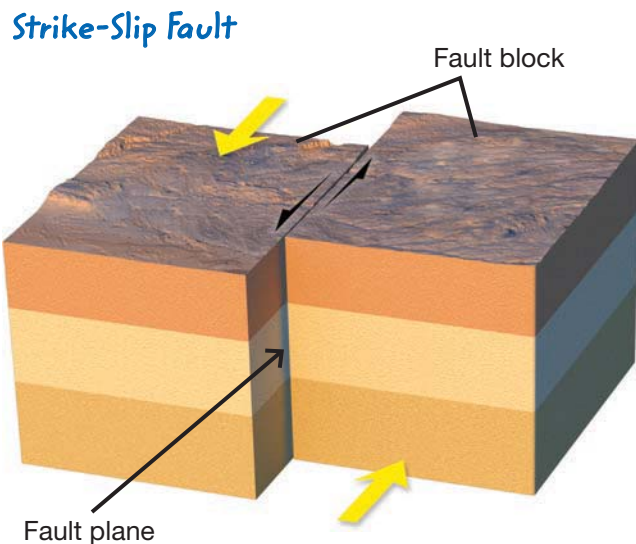
The movement of faults can create mountains and other types of landforms. At any tectonic plate boundary, the amount of stress on rock is complex. Therefore, any of the three types of faults can occur at almost all plate boundaries.

ACTIVE READING

9 Identify As you read, underline the direction of movement of the fault blocks in each type of fault.

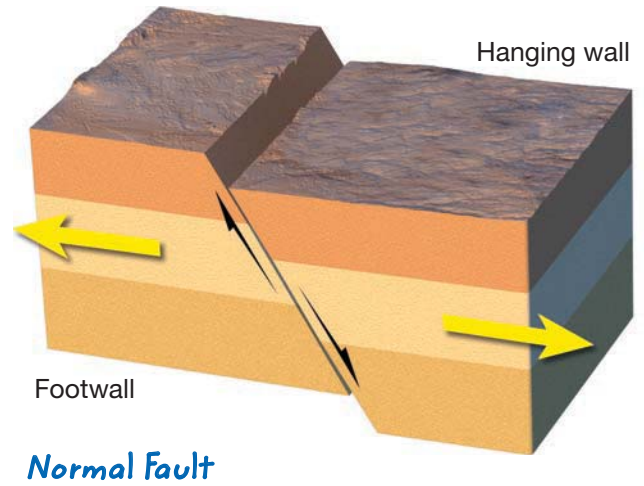
Strike-Slip Faults

In a strike-slip fault, the fault blocks move past each other horizontally. Strike-slip faults form when rock is under shear stress. **Shear stress** is stress that pushes rocks in parallel but opposite directions as seen in the image. As rocks are deformed deep in Earth's crust, energy builds. The release of this energy can cause earthquakes as the rocks slide past each other. Strike-slip faults are common along transform boundaries, where tectonic plates move past each other. The San Andreas fault system in California is an example of a strike-slip fault.



Normal Faults

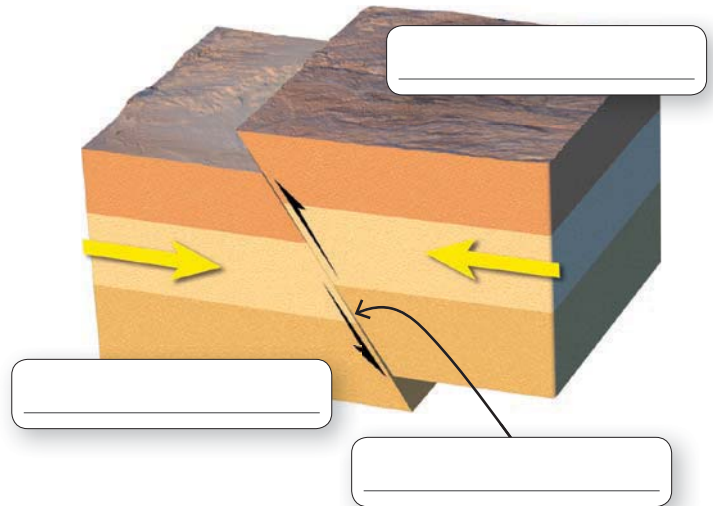
In the normal fault shown on the right, the hanging wall moves down relative to the footwall. The faults are called normal because the blocks move in a way that you would *normally* expect as a result of gravity. Normal faults form when the rock is under tension. **Tension** (TEN•shun) is stress that stretches or pulls rock apart. Therefore, normal faults are common along divergent boundaries. Earth's crust can also stretch in the middle of a tectonic plate. The Basin and Range area of the southwestern United States is an example of a location with many normal fault structures.



Reverse Faults

In the reverse fault shown on the right, the hanging wall moves up relative to the footwall. The faults are called reverse because the hanging blocks move up, which is the reverse of what you would expect as a result of gravity. Reverse faults form when rocks undergo compression. **Compression** (kuhm•PRESH•uhn) is stress that squeezes or pushes rock together. Reverse faults are common along convergent boundaries, where two plates collide. The San Gabriel Mountains in the United States are caused by reverse faults.

Reverse Fault



Visualize It!

10 Identify Label the fault plane, hanging wall, and footwall on the reverse fault to the right.

Think Outside the Book

11 Compile Create a memory matching game of the types of faults. Create as many cards as you can with different photos, drawings, or written details about the types of faults. Use the cards to quiz yourself and your classmates.

Moving On Up

What are the three kinds of mountains?

The movement of energy as heat and material in Earth's interior contribute to tectonic plate motions that result in mountain building. Mountains can form through folding, volcanism, and faulting. *Uplift*, a process that can cause land to rise can also contribute to mountain building. Because tectonic plates are always in motion, some mountains are constantly being uplifted.

ACTIVE READING

12 Identify As you read, underline examples of folded, volcanic, and fault-block mountains.



Folded Mountains

Folded mountains form when rock layers are squeezed together and pushed upward. They usually form at convergent boundaries, where plates collide. For example, the Appalachian Mountains (ap•uh•LAY•chun) formed from folding and faulting when the North American plate collided with the Eurasian and African plates millions of years ago.

In Europe, the Pyrenees (PIR•uh•neez) are another range of folded mountains, as shown below. They are folded over an older, pre-existing mountain range. Today, the highest peaks are over 3,000 m tall.



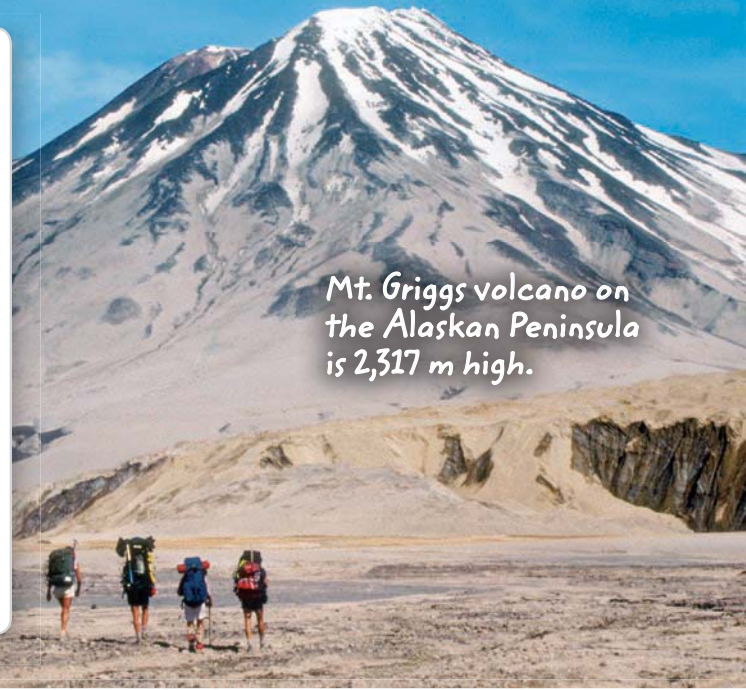
Visualize It!

13 Claims • Evidence • Reasoning What evidence do you see that the Pyrenees Mountains are folded mountains? Summarize evidence to support the claim and explain your reasoning.

The Pyrenees Mountains are folded mountains that separate France from Spain.

Volcanic Mountains

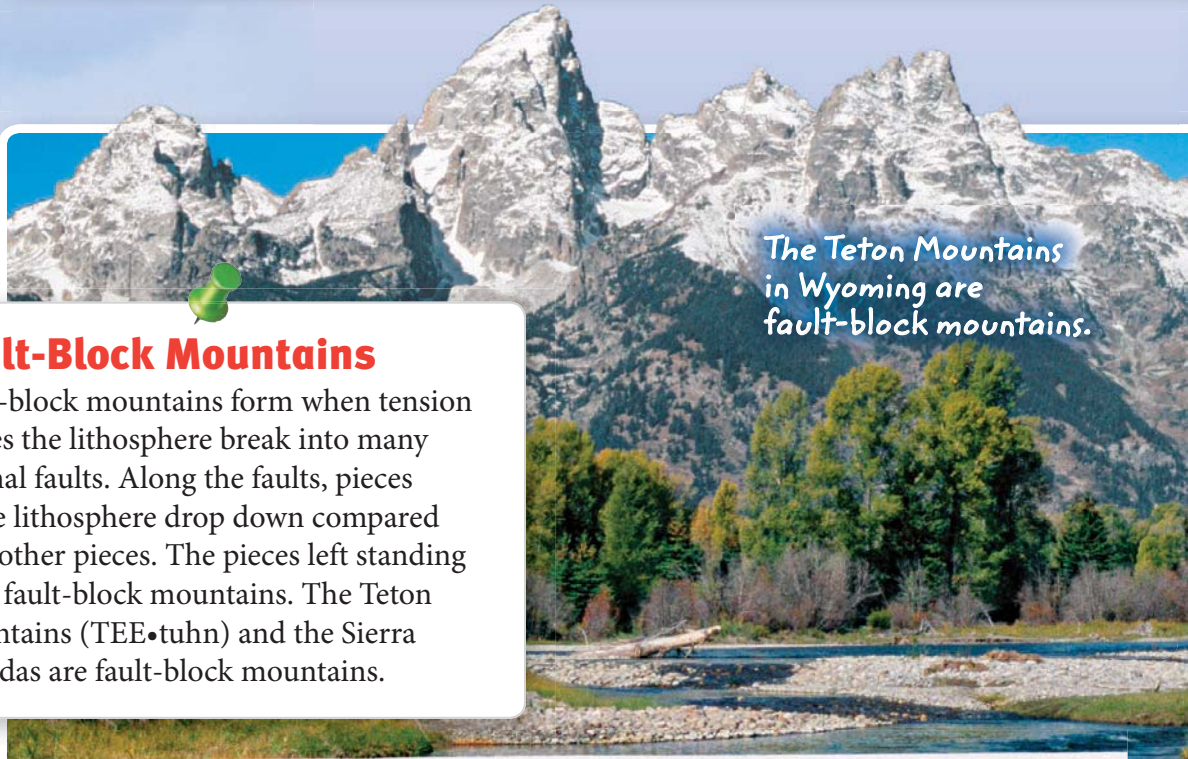
Volcanic mountains form when melted rock erupts onto Earth's surface. Many major volcanic mountains are located at convergent boundaries. Volcanic mountains can form on land or on the ocean floor. Volcanoes on the ocean floor can grow so tall that they rise above the surface of the ocean, forming islands. Most of Earth's active volcanoes are concentrated around the edge of the Pacific Ocean. This area is known as the Ring of Fire. Many volcanoes, including Mt. Griggs in the image to the right, are located on the Northern rim of the Pacific plate in Alaska.



Mt. Griggs volcano on the Alaskan Peninsula is 2,317 m high.

Fault-Block Mountains

Fault-block mountains form when tension makes the lithosphere break into many normal faults. Along the faults, pieces of the lithosphere drop down compared with other pieces. The pieces left standing form fault-block mountains. The Teton Mountains (TEE•tuhn) and the Sierra Nevadas are fault-block mountains.



The Teton Mountains in Wyoming are fault-block mountains.

14 Identify Draw a simple version of each type of mountain below.

Folded

Volcanic

Faulted

Folded	Volcanic	Faulted

Visual Summary

To complete this summary, fill in the blanks with the correct word or phrase. You can use this page to review the main concepts of the lesson.

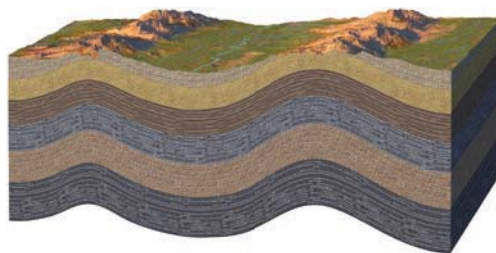
Mountain Building

Rocks can bend or break under stress.



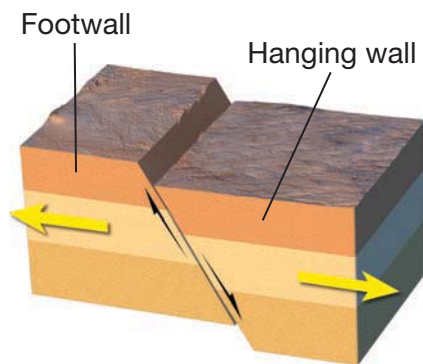
15 The process by which rocks change shape under stress is called _____.

Folds occur when rock layers bend.



16 A rock structure with the oldest rocks at the core of the fold is called a/an _____.

Faults occur when rock layers break.



17 The type of fault pictured is a _____ fault.

Mountains form through folding, volcanism, and faulting.



18 The type of mountains pictured are _____ mountains.

19 Claims • Evidence • Reasoning The middle of tectonic plates tend to have fewer mountains than locations near tectonic plate boundaries. Make a claim about what might be one possible explanation for this. Summarize evidence to support the claim and explain your reasoning.

Vocabulary

Fill in the blank with the term that best completes the following sentences.

- 1 A normal fault is a result of a type of stress known as _____
- 2 A strike-slip fault is a result of _____ stress.
- 3 A reverse fault is caused by a type of stress known as _____

Key Concepts

Fill in the table below by identifying the type of mountain described in the example question.

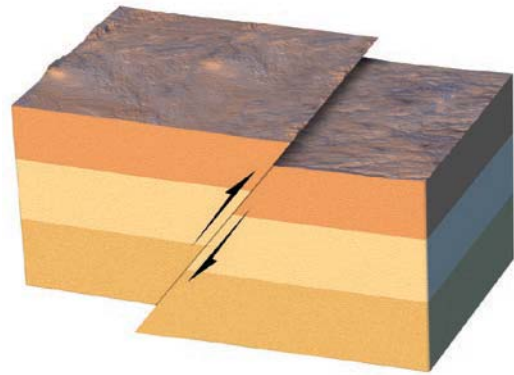
Example	Type of Mountain
4 Identify The Basin and Range province is characterized by many normal faults.	
5 Identify The Cascade Range in the United States has many eruptive mountains.	
6 Identify The Pyrenees Mountains have many syncline and anticline structures.	

7 Describe How does the movement of tectonic plates cause deformation in rock?

8 Compare How do folded, volcanic, and fault-block mountains differ?

Critical Thinking

Use the diagram below to answer the following questions.



9 Correlate What type of stress caused the fault shown in the image?

10 Claims • Evidence • Reasoning Make a claim about along which type of tectonic plate boundary this fault would be common. Provide evidence to support the claim and explain your reasoning.

11 Claims • Evidence • Reasoning Make a claim about whether a rock can undergo compression, tension, and shear stress all at once. Summarize evidence to support the claim and explain your reasoning.

12 Conclude Imagine you are walking along a roadway and see a syncline. What can you conclude about the formation of that fold?

Earthquakes

ESSENTIAL QUESTION

Why do earthquakes happen?

By the end of this lesson, you should be able to describe the causes of earthquakes and to identify where earthquakes happen.



SC.7.N.1.1 Define a problem from the seventh grade curriculum, use appropriate reference materials to support scientific understanding, plan and carry out scientific investigation of various types, such as systematic observations or experiments, identify variables, collect and organize data, interpret data in charts, tables, and graphics, analyze information, make predictions, and defend conclusions. **SC.7.E.6.5** Explore the scientific theory of plate tectonics by describing how the movement of Earth's crustal plates causes both slow and rapid changes in Earth's surface, including volcanic eruptions, earthquakes, and mountain building. **SC.7.E.6.7** Recognize that heat flow and movement of material within Earth causes earthquakes and volcanic eruptions, and creates mountains and ocean basins.



The 1995 Kobe earthquake in Japan destroyed more than 200,000 buildings and structures including this railroad track.

Lesson Labs

Quick Labs

- Elastic Rebound
- Earthquake Vibrations
- Earthquakes and Buildings

S.T.E.M. Lab

- Use a Seismograph to Determine the Amount of Energy in an Earthquake



Engage Your Brain

1 Predict Fill in any words or numbers that you think best complete each of the statements below.

Each year there are approximately _____ earthquakes detected around the world.

In the United States, the state with the most earthquakes on average is _____.

Every year, earthquakes cause _____ of dollars in damages in the United States.

Most earthquakes only last for several _____ of time.

2 Analyze Using the image, list in column 1 some of the hazards that can occur after an earthquake. In column 2, explain why you think these items or situations would be hazardous.

Hazards	Why?

ACTIVE READING

3 Synthesize You can often define an unknown word if you know the meaning of its word parts. Use the word parts and sentence below to make an educated guess about the meaning of the word *epicenter*.

Word part	Meaning
<i>epi-</i>	on, upon, or over
<i>-center</i>	the middle

Example sentence

The epicenter of the earthquake was only 3 km from our school.

epicenter:

Vocabulary Terms

- earthquake
- focus
- epicenter
- tectonic plate boundary
- fault
- deformation
- elastic rebound

4 Apply As you learn the definition of each vocabulary term in this lesson, create your own definition or sketch to help you remember the meaning of the term.

Let's Focus

What is an earthquake?

Earthquakes can cause extreme damage and loss of life. **Earthquakes** are ground movements that occur when blocks of rock in Earth move suddenly and release energy. The energy is released as seismic waves which cause the ground to shake and tremble.

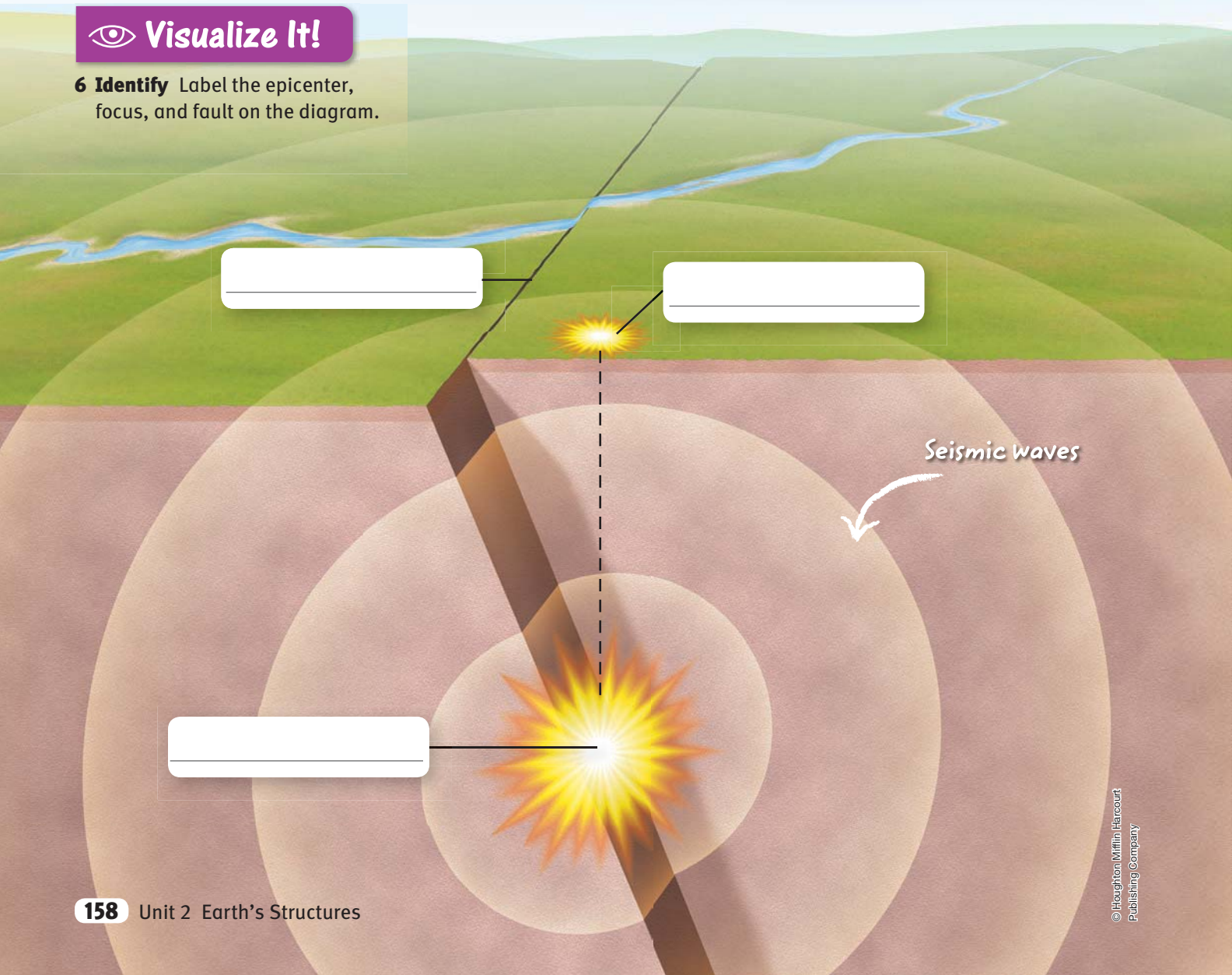
Earthquake waves can be tracked to a point below Earth's surface known as the focus. The **focus** is a place within Earth along a fault at which the first motion of an earthquake occurs. Motion along a fault causes stress. When the stress on the rock is too great, the rock will rupture and cause an earthquake. The earthquake releases the stress. Directly above the focus on Earth's surface is the **epicenter** (EP•i•sen•ter). Seismic waves flow outward from the focus in all directions.

ACTIVE READING

5 Identify As you read, underline the definitions of *focus* and *epicenter*.

Visualize It!

6 Identify Label the epicenter, focus, and fault on the diagram.



What causes earthquakes?

Most earthquakes occur near the boundaries of tectonic plates. A **tectonic plate boundary** is where two or more tectonic plates meet. As tectonic plates move, pressure builds up near the edges of the plates. These movements break Earth's crust into a series of faults. A **fault** is a break in Earth's crust along which blocks of rock move. The release of energy that accompanies the movement of the rock along a fault causes an earthquake.

Elastic Rebound

When rock is put under tremendous pressure, stress may deform, or change the shape of, the rock. **Deformation** (dee•for•MAY•shun) is the process by which rock becomes deformed and changes shape due to stress. As stress increases, the amount of energy that is stored in the rock increases, as seen in image B to the right.

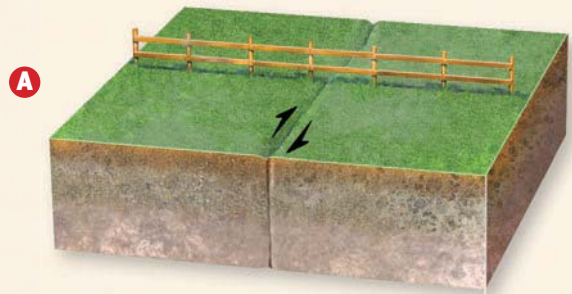
Stress can change the shape of rock along a fault. Once the stress is released, rock may return to its original shape. When rock returns to nearly the same shape after the stress is removed, the process is known as *elastic deformation*. Imagine an elastic band that is pulled tight under stress. Once stress on the elastic band is removed, there is a *snap!* The elastic band returns to its original shape. A similar process occurs during earthquakes.

Similar to an elastic band, rock along tectonic plate boundaries can suddenly return to nearly its original shape when the stress is removed. The sudden *snap* is an earthquake. The return of rock to its original shape after elastic deformation is called **elastic rebound**. Earthquakes accompany the release of energy during elastic rebound. When the rock breaks and rebounds, it releases energy as seismic waves. The seismic wave energy radiates from the focus of the earthquake in all directions. This energy causes the ground to shake for a short time. Most earthquakes last for just a few seconds.



Visualize It!

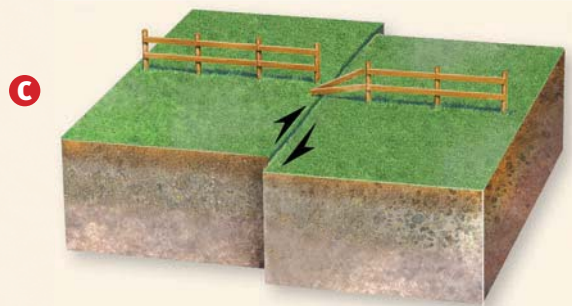
7 Claims • Evidence • Reasoning Make a claim about whether an earthquake occurred between images A and B or between images B and C. Summarize evidence to support the claim and explain your reasoning.



Along a fault, rocks are pushed or pulled in different directions and at different speeds.



As stress increases and energy builds within the rock, the rock deforms but remains locked in place.



Too much stress causes the rock to break and rebound to its original shape, releasing energy.

Unstable Ground

Where do earthquakes happen?

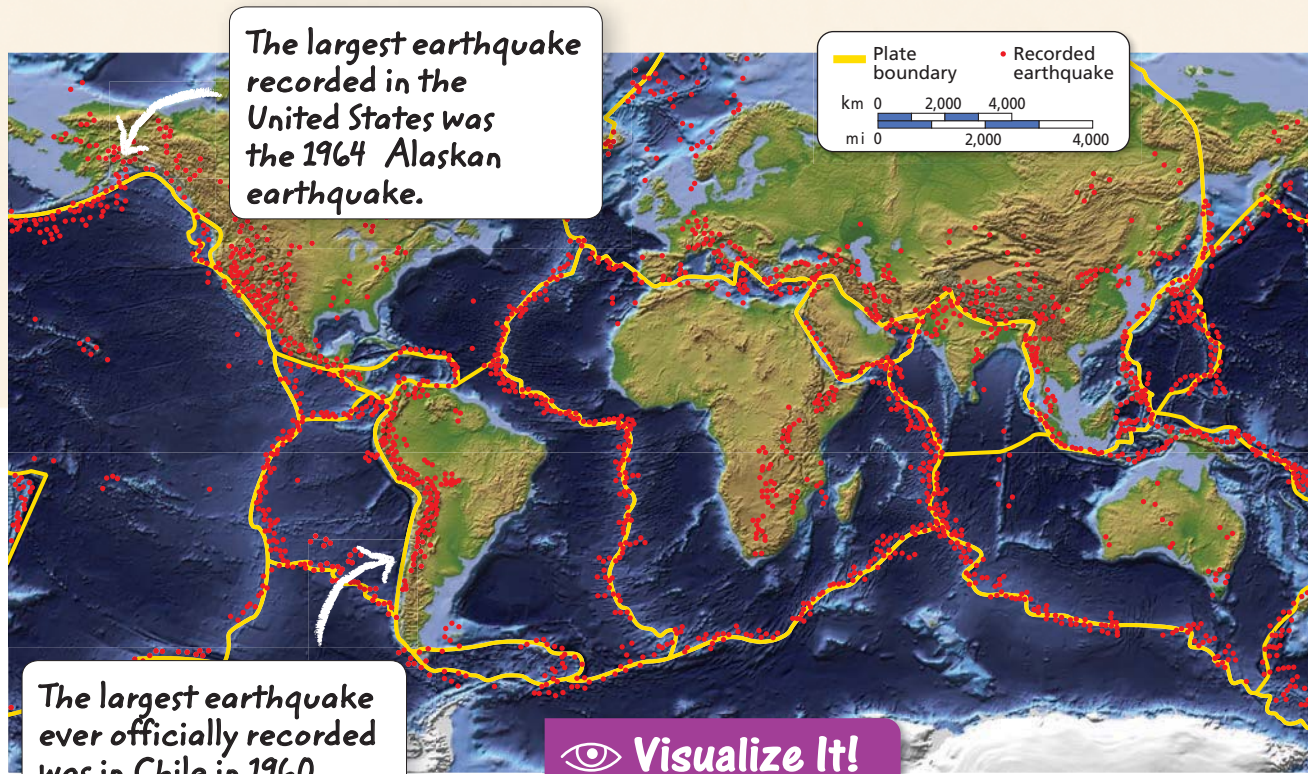
ACTIVE READING

8 Identify As you read, underline the locations where earthquakes occur.

Each year, approximately 500,000 earthquakes are detected worldwide. The map below shows some of these earthquakes. Movement of material and energy in the form of heat in Earth's interior contribute to plate motions that result in earthquakes.

Most earthquakes happen at or near tectonic plate boundaries. Tectonic plate boundaries are areas where Earth's crust experiences a lot of stress. This stress occurs because the tectonic plates are colliding, separating, or grinding past each other horizontally. There are three main types of tectonic plate boundaries: divergent, convergent, and transform. The movement and interactions of the plates causes the crust to break into different types of faults. Earthquakes happen along these faults.

Plate Tectonic Boundaries and Earthquake Locations Worldwide



Visualize It!

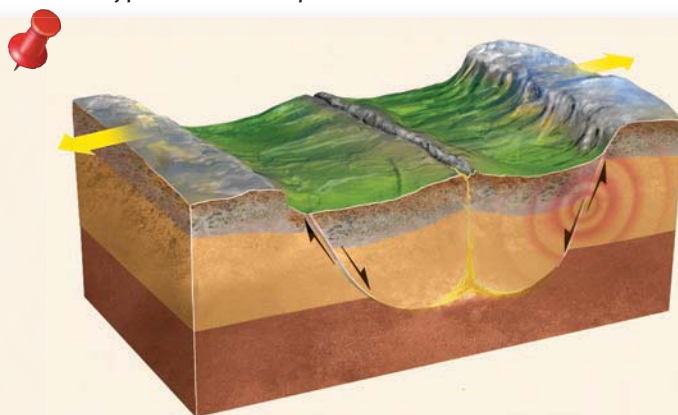
9 Claims • Evidence • Reasoning Make a claim about where most of Earth's earthquakes are located. Summarize evidence to support the claim and explain your reasoning.

10 Correlate In the caption for each diagram, write in the type of fault that is common at each of the types of tectonic plate boundaries.

At Divergent Boundaries

At a divergent boundary, plates pull apart, causing the crust to stretch. Stress that stretches rock and makes rock thinner is called *tension*. Normal faults commonly result when tension pulls rock apart.

Most of the crust at divergent boundaries is thin, so the earthquakes tend to be shallow. Most earthquakes at divergent boundaries are no more than 20 km deep. A mid-ocean ridge is an example of a divergent boundary where earthquakes occur.

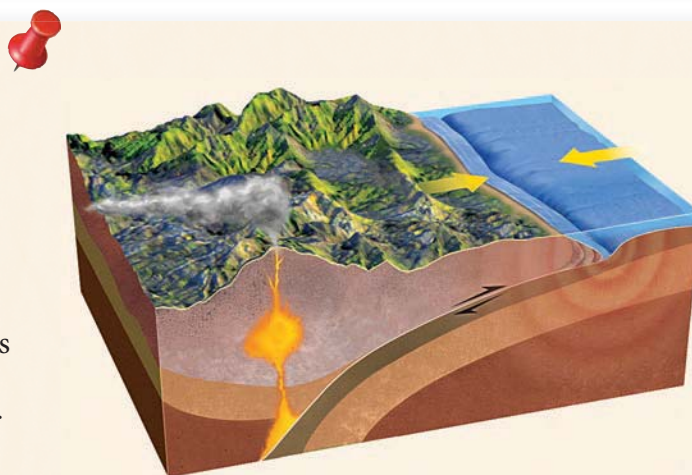


At divergent boundaries, earthquakes are common along _____ faults.

At Convergent Boundaries

Convergent plate boundaries occur when plates collide, causing rock to be squeezed. Stress that shortens or squeezes an object is known as *compression*. Compression causes the formation of reverse faults. Rocks are thrust over one another at reverse faults.

When two plates come together, both plates may crumple up to form mountains. Or one plate can subduct, or sink, underneath the other plate and into the mantle. The earthquakes that happen at convergent boundaries can be very strong. Subduction zone earthquakes occur at depths of up to 700 km.

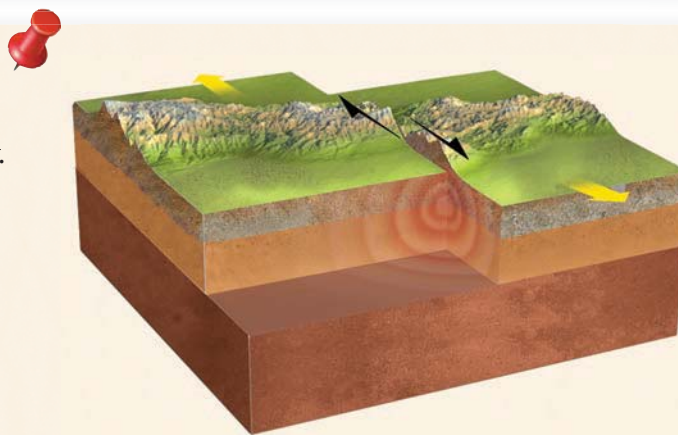


At convergent boundaries, earthquakes are common along _____ faults.

At Transform Boundaries

A transform boundary is a place where two tectonic plates slide past each other horizontally. Stress that distorts a body by pushing different parts of the body in opposite directions is called *shear stress*. As the plates move, rocks on both sides of the fault are sheared, or broken, as they grind past one another in opposite directions.

Strike-slip faults are common at transform boundaries. Most earthquakes along the faults at transform boundaries are relatively shallow. The earthquakes are generally within the upper 50 km of the crust.



At transform boundaries, earthquakes are common along _____ faults.

i Think Outside the Book

11 Design You are an emergency management professional. You have been assigned to create an earthquake safety brochure for your town. Create a brochure that demonstrates ways people can protect themselves during an earthquake.

Although most of this building is left standing, the entire area is a hazard to citizens in the town.



What are some effects of earthquakes?

Many earthquakes do not cause major damage. However, some strong earthquakes can cause billions of dollars in property damage. Earthquakes may even cause human injuries and loss of life. In general, areas closest to the epicenter of an earthquake experience the greatest damage.

Danger to People and Structures

The shaking of an earthquake can cause structures to move vertically and horizontally. When structures cannot withstand the shaking, major destruction can occur. Following the release of seismic waves, buildings can shake so violently that a total or partial collapse can happen, as shown below.

Much of the injury and loss of life that happen during and after earthquakes is caused by structures that collapse. In addition, fires, gas leaks, floods, and polluted water supplies can cause secondary damages following an earthquake. The debris left after an earthquake can take weeks or months to clean up. Bridges, roadways, homes, and entire cities can become disaster zones.

Tsunamis

An earthquake under the ocean can cause a vertical movement of the sea floor that displaces an enormous amount of water. This displacement may cause a tsunami to form. A *tsunami* (sue•NAH•mee) is a series of extremely long waves that can travel across the ocean at speeds of up to 800 km/h. Tsunami waves travel outward in all directions from the point where the earthquake occurred. As the waves approach a shoreline, the size of the waves increases. The waves can be taller than 30 m. Tsunami waves can cause major destruction and take many lives as they smash and wash away anything in their path. Many people may drown during a tsunami. Floods, polluted water supplies, and large amount of debris are common in the aftermath.

12 Identify List some of the hazards associated with earthquakes on land and underwater.

On Land	Underwater

WHY IT MATTERS

Killer Quake

A CHANGING
WORLD

Imagine losing half the people in your city. On December 26, 2004, a massive tsunami destroyed approximately one-third of the buildings in Banda Aceh, Indonesia, and wiped out half the population.



Before



How Tsunamis Form

In the ocean, tsunami waves are fast but not very tall. As the waves approach a coast, they slow down and get much taller.

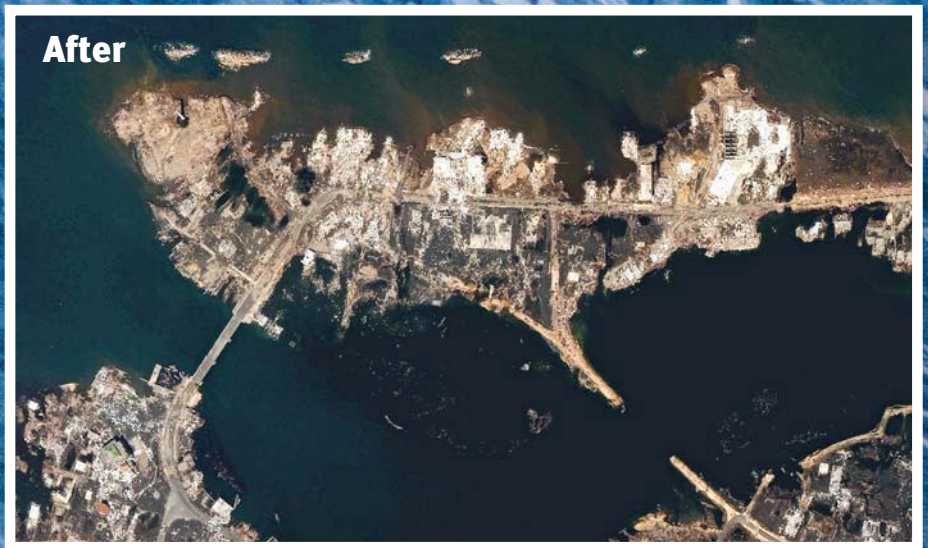
Before the Earthquake

The Banda Aceh tsunami resulted from a very strong earthquake in the ocean. Banda Aceh was very close to the epicenter.

Major Damages

The destruction to parts of Asia were so massive that geographers had to redraw the maps of some of the countries.

After



i Extend

13 Identify In what ocean did the earthquake occur?

14 Research Investigate one other destructive tsunami and find out where the earthquake that caused it originated.

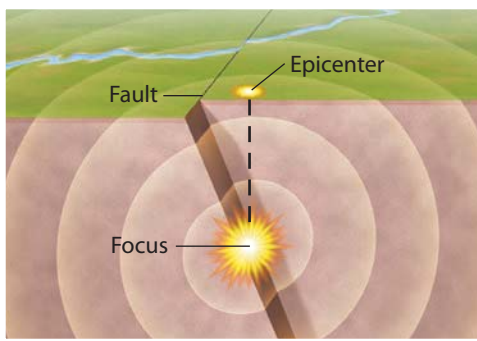
15 Claims • Evidence • Reasoning Many of the people affected by the tsunami were poor. Make a claim about why earthquakes might be more damaging in poor areas of the world. Support the claim with evidence, and explain your reasoning.

Visual Summary

To complete this summary, fill in the correct word. You can use this page to review the main concepts of the lesson.

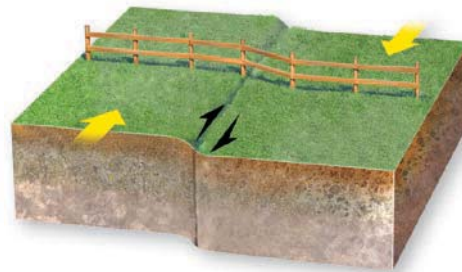
Earthquakes

Earthquakes occur along faults.



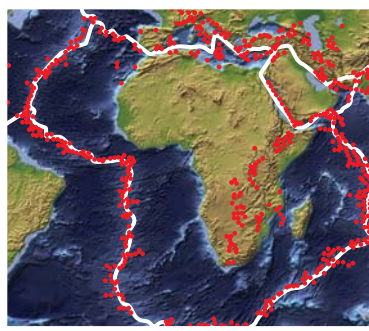
16 The epicenter of an earthquake is directly above the _____

Rocks break and snap back to their original shape in an earthquake.



17 Earthquakes happen when rocks bend and snap back in a process called _____

Earthquakes usually happen along plate boundaries.



18 The three types of plate boundaries are _____

Earthquakes can cause a lot of damage.



19 An example of the dangers of earthquakes is _____

20 Claims • Evidence • Reasoning Make a claim about whether or not earthquakes can be prevented. Summarize evidence to support the claim and explain your reasoning.

Vocabulary

In your own words, define the following terms.

1 Elastic rebound

2 Focus

3 Fault

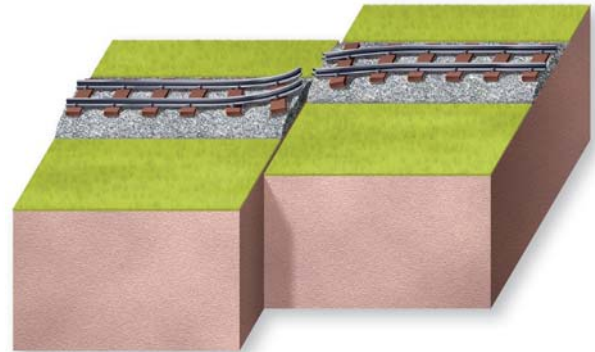
Key Concepts

Example	Type of Boundary
4 Identify Most of the earthquakes in Japan are a result of one plate sinking under another.	
5 Identify The African Rift Valley is a location where plates are moving apart.	
6 Identify The San Andreas fault is a location where tectonic plates move horizontally past each other.	

7 Explain What causes an earthquake?

Critical Thinking

Use the image to answer the following questions.



8 Claims • Evidence • Reasoning Make a claim about how the image above demonstrates that a deformation has taken place. Summarize evidence to support the claim and explain your reasoning.

9 Apply How do Earth's surface and the structures on the surface change as a result of an earthquake?

10 Claims • Evidence • Reasoning Make a claim about why there is often only a short amount of time to evacuate an area before an earthquake. Use evidence to support the claim and explain your reasoning.



SC.7.N.1.3 Distinguish between an experiment (which must involve the identification and control of variables) and other forms of scientific investigation and explain that not all scientific knowledge is derived from experimentation.

S.T.E.M. ENGINEERING & TECHNOLOGY

Engineering Design Process

Skills
Identify a need
Conduct research
✓ Brainstorm solutions
✓ Select a solution
Design a prototype
✓ Build a prototype
✓ Test and evaluate
✓ Redesign to improve
✓ Communicate results

Objectives
Explain how scientists measure the energy of earthquakes.
Design a model seismometer to measure motion.
Test and modify a prototype to achieve a desired result.

Building a Seismometer

An earthquake occurs when rocks beneath the ground move suddenly. The energy of this movement travels through Earth in waves. Sometimes the shaking is detected hundreds or thousands of miles away from the origin of the earthquake. Scientists can learn about earthquakes by measuring the earthquake waves.

Measuring Motion

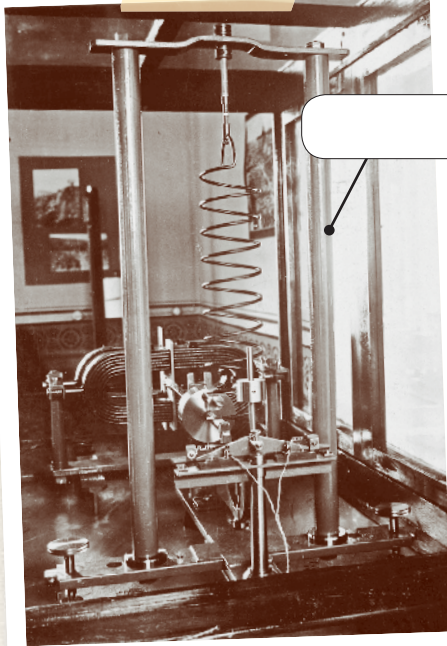
A seismometer is a device for measuring the motion of the ground beneath it. To develop seismometers, scientists had to solve a problem: How do you keep one part of the device from moving when the ground moves? The solution can be seen in the design shown here. A spring separates a heavy weight from the frame of the seismometer. Attached to the weight is a pen. The tip of the pen touches the surface of a circular drum that is covered in paper and slowly turning. When the ground moves, the frame and the rotating drum move along with it. The spring absorbs the ground's movement, so the weight and pen do not move. The pen is always touching the paper on the rotating drum. When the ground is not moving, the pen draws a straight line. When the ground moves, the pen draws this movement.

Waves move the instrument, but the spring and weight keep the pen still.

1 Claims • Evidence • Reasoning This instrument measures the up-and-down motion of earthquake waves. Make a claim about how to change the instrument to measure the side-to-side motion of an earthquake. Support the claim with evidence and explain your reasoning.



2 Infer In the oval below, write *moves* or *still* to indicate whether the labeled part moves during an earthquake or remains still.

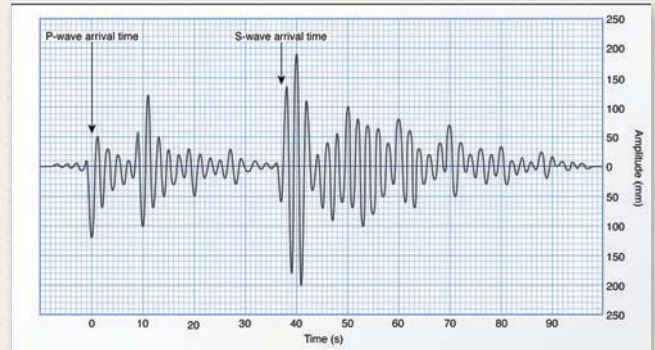


The spring in this older type of seismometer absorbs energy. Modern seismometers use electronic components instead of giant springs.

Drawing the Waves

The drawing produced by a seismometer is called a *seismogram*. A seismogram shows two kinds of earthquake waves: P waves and S waves. P waves move through Earth's crust faster than S waves do. Seismologists measure the time between the arrival of P waves and the arrival of S waves to calculate how far away the earthquake occurred.

Seismogram



3 Claims • Evidence • Reasoning Make a claim about how geologists might use seismograms to find the exact location of an earthquake. Support the claim with evidence, and explain your reasoning.

You Try It!



Now it's your turn to design and build a seismometer.

You Try It!

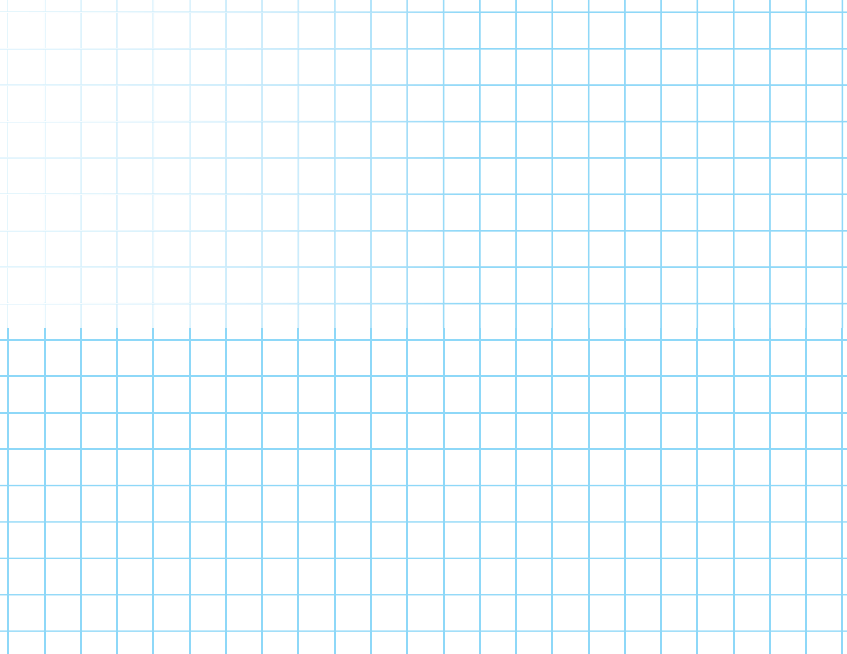
Now you will build a seismometer that can detect motion. You will use your seismometer to record the motion of a table. To do this, you will need to determine which parts of your seismometer will move and which parts will remain still. After you design and build the prototype, slowly shake the table back and forth. You may need to redesign and try again.

1 Brainstorm Solutions

In your group, brainstorm ideas for a seismometer that will measure side-to-side movement of a surface, such as a table. When the seismometer is placed on a table, it must record the motion of the table when the table is bumped. Use the space below to record ideas as you brainstorm a solution.

2 Select a Solution

Draw a prototype of your group's seismometer idea in the space below. Be sure to include all the parts you will need and show how they will be connected.



You Will Need

- ✓ large square wooden frame
- ✓ metal weights
- ✓ string
- ✓ fine point felt tip pen
- ✓ long strips or roll of paper
- ✓ tape
- ✓ various hooks and hardware



3 Build a Prototype

In your group, build the seismometer. As the group builds it, are there some aspects of the design that cannot be assembled as predicted? What did the group have to revise in the prototype?

4 Test and Evaluate

Bump or shake the table under the seismometer. Did the prototype record any motion on the paper strip? If not, what can you revise?

5 Redesign to Improve

Choose one aspect to revise, and then test again. Keep making revisions, one at a time, until your seismometer records the motion of the table. How many revisions did the group make?

6 Communicate Results

Claims • Evidence • Reasoning Report your observations about the prototype seismometer. Include changes that improved its performance or decreased its performance. Make a claim about ways you could have built a more accurate seismometer, including what additional materials you would need and what they would be used for. Provide evidence to support the claim and explain your reasoning.

Volcanoes

ESSENTIAL QUESTION

How do volcanoes change Earth's surface?

By the end of this lesson, you should be able to describe what the various kinds of volcanoes and eruptions are, where they occur, how they form, and how they change Earth's surface.



SC.7.E.6.5 Explore the scientific theory of plate tectonics by describing how the movement of Earth's crustal plates causes both slow and rapid

changes in Earth's surface, including volcanic eruptions, earthquakes, and mountain building.

SC.7.E.6.7 Recognize that heat flow and movement of material within Earth causes earthquakes and volcanic eruptions, and creates mountains and ocean basins.

The Arenal volcano in Costa Rica has been active since 1968. The volcano has erupted on and off for over 7,000 years.

Lesson Labs

Quick Lab

- Modeling an Explosive Eruption
- Volcano Mapping



Engage Your Brain

1 Predict Check T or F to show whether you think each statement is true or false.

- | T | F | |
|--------------------------|--------------------------|--|
| <input type="checkbox"/> | <input type="checkbox"/> | Volcanoes create new landforms such as mountains. |
| <input type="checkbox"/> | <input type="checkbox"/> | Tectonic plate boundaries are the only locations where volcanoes form. |
| <input type="checkbox"/> | <input type="checkbox"/> | Volcanic eruptions are often accompanied by earthquakes. |
| <input type="checkbox"/> | <input type="checkbox"/> | Volcanoes form new rocks and minerals. |

2 Hypothesize You are a news reporter assigned to cover a story about the roadway in the image below. Describe what you think happened in this photo.

ACTIVE READING

3 Synthesize You can often define an unknown word if you know the meaning of its word parts. Use the word parts and sentence below to make an educated guess about the meaning of the word *pyroclastic*.

Word part	Meaning
<i>pyro-</i>	heat or fire
<i>-clastic</i>	pieces

Example sentence

Pyroclastic material was ejected into the atmosphere with explosive force during the eruption of the volcano.

pyroclastic:

Vocabulary Terms

- volcano
- magma
- lava
- vent
- tectonic plate
- hot spot

4 Apply As you learn the definition of each vocabulary term in this lesson, create your own definition or sketch to help you remember the meaning of the term.

Magma MAGIC

What is a volcano?

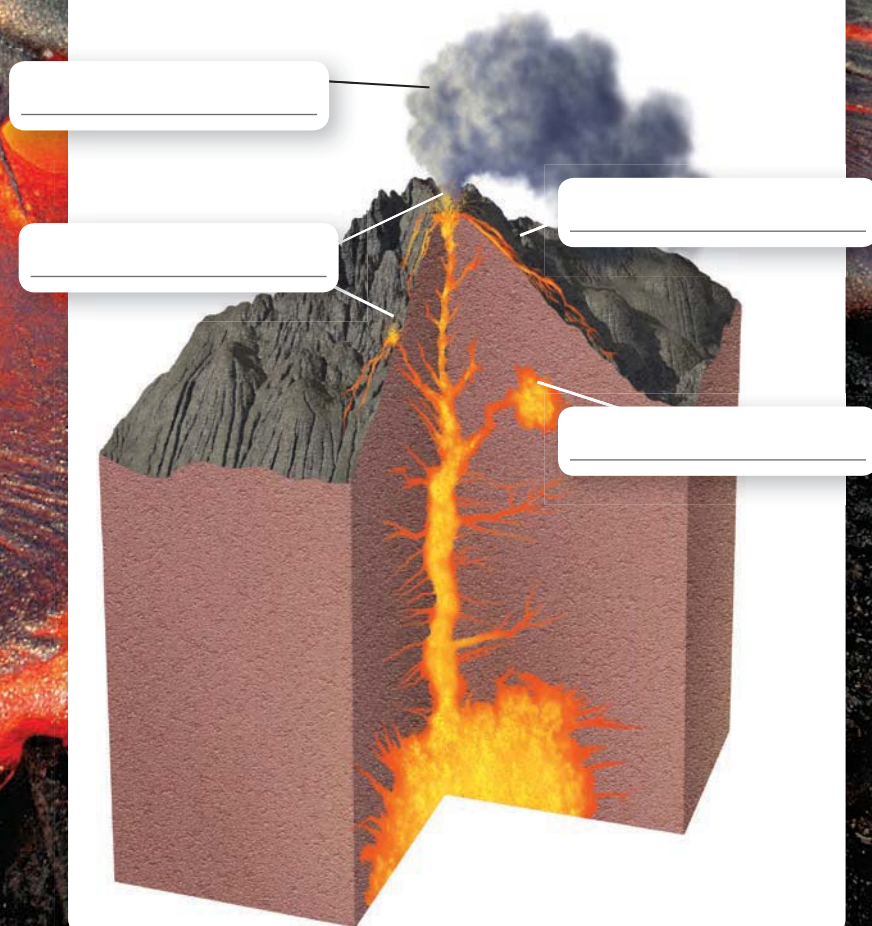
What do volcanoes look like? Most people think of a steep mountain with smoke coming out of the top. In fact, a **volcano** is any place where gas, ash, or melted rock come out of the ground. A volcano can be a tall mountain, as shown below, or a small crack in the ground. Volcanoes occur on land and underwater. There are even volcanoes on other planets. Not all volcanoes actively erupt. Many are *dormant*, meaning an eruption has not occurred in a long period of time.

Volcanoes form as rock below the surface of Earth melts. The melted rock, or **magma**, is less dense than solid rock, so it rises toward the surface. **Lava** is magma that has reached Earth's surface. Lava and clouds of ash can erupt from a **vent**, or opening of a volcano.

Visualize It!

5 Identify Label the parts of the volcano. Include the following terms: *magma, lava, vent, ash cloud*.

Lava can reach temperatures of more than 1,200 °C.



(Clockwise from top left) © Stephen & Donna O'Ware/Photo Researchers, Inc.

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What are the kinds of volcanic landforms?

The location of a volcano and the composition of magma determine the type of volcanic landforms created. Shield volcanoes, cinder cones, composite volcanoes, lava plateaus, craters, and calderas are all types of volcanic landforms.

Volcanic Mountains

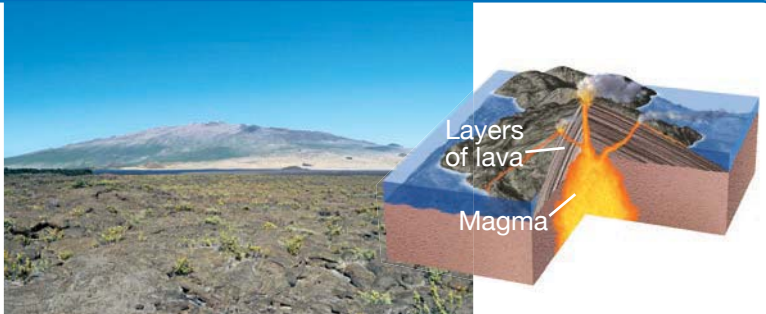
Materials ejected from a volcano may build up around a vent to create volcanic mountains. *Viscosity* (vyz•SKAHZ•ih•tee) is the resistance of a liquid material, such as lava, to flow. The viscosity of lava determines the explosiveness of an eruption and the shape of the resulting volcanic mountain. Low-viscosity lava flows easily, forms low slopes, and erupts without large explosions. High-viscosity lava does not flow easily, forms steep slopes, and can erupt explosively. *Pyroclastic materials* (py•roh•KLAHZ•tyk), or hot ash and bits of rock, may also be ejected into the atmosphere.

6 Apply Small fragments of rock material that are ejected from a volcano are known as *volcanic ash*. Volcanic ash is a form of pyroclastic material. The material does not dissolve in water and is very abrasive, meaning it can scratch surfaces. Ash can build up to great depths in locations around a volcano. Write a cleanup plan for a town that explains how you might safely remove and dispose of volcanic ash.

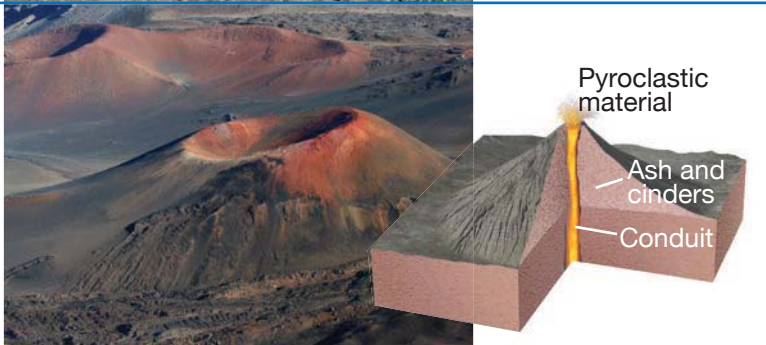
ACTIVE READING

7 Identify As you read, underline the main features of each type of volcanic mountain.

• **Shield Volcanoes** Volcanoes with a broad base and gently sloping sides are *shield volcanoes*. Shield volcanoes cover a wide area and generally form from mild eruptions. Layers of lava flow out from the vent, harden, and slowly build up to form the cone. The Hawaiian Islands are shield volcanoes.



• **Cinder Cones** Sometimes, ash and pieces of lava harden in the air and can fall to the ground around a small vent. The hardened pieces of lava are called cinders. The cinders and ash build up around the vent and form a steep volcano called a *cinder cone*. A cinder cone can also form at a side vent on other volcanic mountains, such as on shield or composite volcanoes.



• **Composite Volcanoes** Alternating layers of hardened lava flows and pyroclastic material create *composite volcanoes* (kuhm•PAHZ•iht). During a mild eruption, lava flows cover the sides of the cone. During an explosive eruption, pyroclastic material is deposited around the vent. Composite volcanoes commonly develop into large and steep volcanic mountains.



(t) © Bernd Mellmann/Alamy; (c) © Photo Tan Yilmaz/Moment/Getty Images; (b) © Tom Mareschal/Alamy

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Fissures and Lava Plateaus

Fissure eruptions (FIH•shohree•RUHP•shuhnz) happen when lava flows from giant cracks, or *fissures*, in Earth's surface. The fissures are found on land and on the ocean floor. A fissure eruption has no central opening. Lava flows out of the entire length of the fissure, which can be many kilometers long. As a result, a thick and mostly flattened layer of cooled lava, called a *lava plateau* (plah•TOH), can form. One example of a lava plateau is the Columbia Plateau Province in Washington, Oregon, and Idaho, as shown to the right.

The Palouse Falls in Washington plunge deep into exposed layers of the Columbia lava plateau.



Craters and Calderas

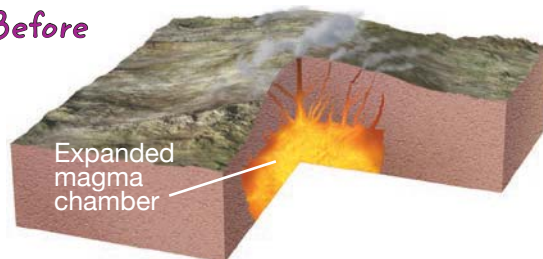
A *volcanic crater* is an opening or depression at the top of a volcano caused by eruptions. Inside the volcano, molten rock can form an expanded area of magma called a *magma chamber*, as shown to the right. When the magma chamber below a volcano empties, the roof of the magma chamber may collapse and leave an even larger, basin-shaped depression called a *caldera* (kahl•DAHR•uh). Calderas can form from the sudden drain of a magma chamber during an explosive eruption or from a slowly emptied magma chamber. More than 7,000 years ago, the cone of Mount Mazama in Oregon collapsed to form a caldera. The caldera later filled with water and is now called Crater Lake.

A caldera can be more than 100 km in diameter.

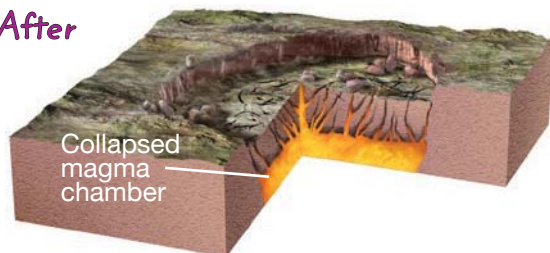
Visualize It!

8 Claims • Evidence • Reasoning Make a claim about how the appearance of land surfaces change before and after a caldera forms. Summarize evidence to support the claim and explain your reasoning.

Before



After



(t) ©BlueMoon Stock/Alamy

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ERUPTION!

Where do volcanoes form?

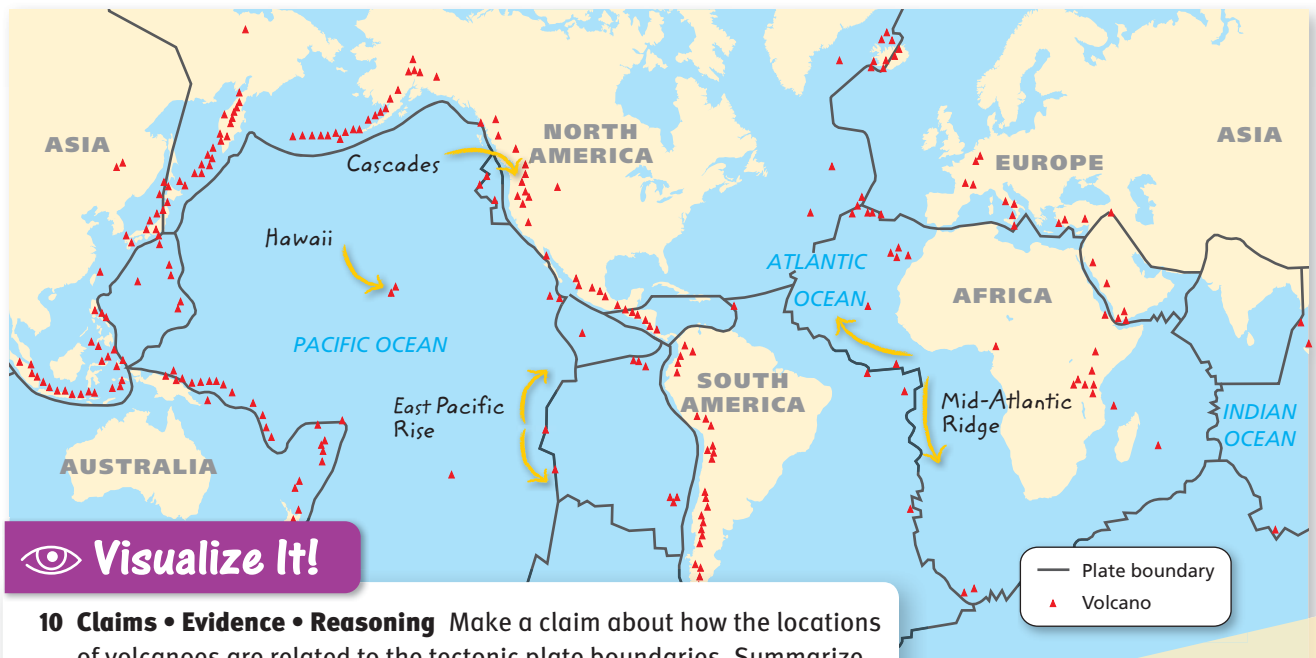
Volcanoes can form at plate boundaries or within the middle of a plate. Recall that **tectonic plates** are giant sections of lithosphere on Earth's surface. Volcanoes can form at *divergent plate boundaries* where two plates are moving away from each other. Most fissure eruptions occur at divergent boundaries. Shield volcanoes, fissure eruptions, and cinder cones can also occur away from plate boundaries within a plate at *hot spots*. The type of lava normally associated with these volcanoes has a relatively low viscosity, few trapped gases, and is usually not explosive.

Composite volcanoes are most common along *convergent plate boundaries* where oceanic plates subduct. In order for the rock to melt, it must be hot and the pressure on it must drop, or water and other fluids must be added to it. Extra fluids from ocean water form magma of higher viscosity with more trapped gases. Thus, composite volcanoes produce the most violent eruptions. The *Ring of Fire* is a name used to describe the numerous explosive volcanoes that form on convergent plate boundaries surrounding the Pacific Ocean.

ACTIVE READING

9 Identify As you read, underline three locations where volcanoes can form.

Plate Tectonic Boundaries and Volcano Locations Worldwide



Visualize It!

10 Claims • Evidence • Reasoning Make a claim about how the locations of volcanoes are related to the tectonic plate boundaries. Summarize evidence to support the claim and explain your reasoning.

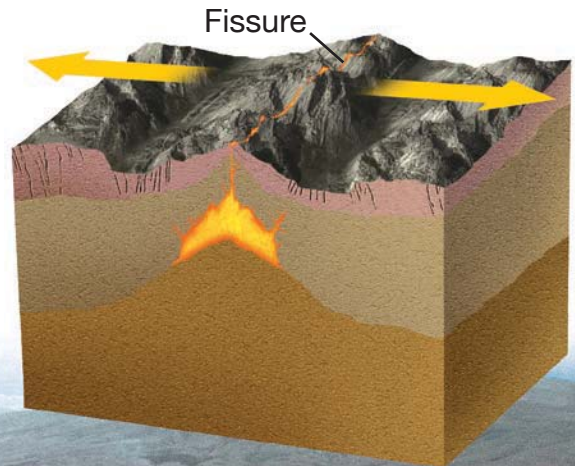
○ At Divergent Boundaries

At divergent boundaries, plates move away from each other. The lithosphere stretches and gets thinner, so the pressure on the mantle rock below decreases. As a result, the asthenosphere bulges upward and magma forms. This magma rises through fissures in the lithosphere, out onto the land or the ocean floor.

Most divergent boundaries are on the ocean floor. When eruptions occur in these areas, undersea volcanoes develop. These volcanoes and other processes lead to the formation of a long, underwater mountain range known as a *mid-ocean ridge*. Two examples of mid-ocean ridges are the East Pacific Rise in the Pacific Ocean and the Mid-Atlantic Ridge in the Atlantic Ocean. The youngest rocks in the ocean are located at mid-ocean ridges.

Shield volcanoes and cinder cones are common in Iceland, where the Mid-Atlantic Ridge runs through the country. As the plates move away from each other, new crust forms. When a divergent boundary is located in the middle of a continent, the crust stretches until a rift valley is formed, as shown below.

Divergent plate boundaries create fissure eruptions and shield volcanoes.



ACTIVE READING

11 Claims • Evidence • Reasoning Make a claim about what types of volcanic landforms occur at divergent plate boundaries. Support your claim with evidence. Explain your reasoning.

The Great Rift Valley in Africa is a location where the crust is stretching and separating.



Tectonic plates move away from each other at divergent boundaries.

(1) © NASA Science Source/Photo Researchers, Inc.

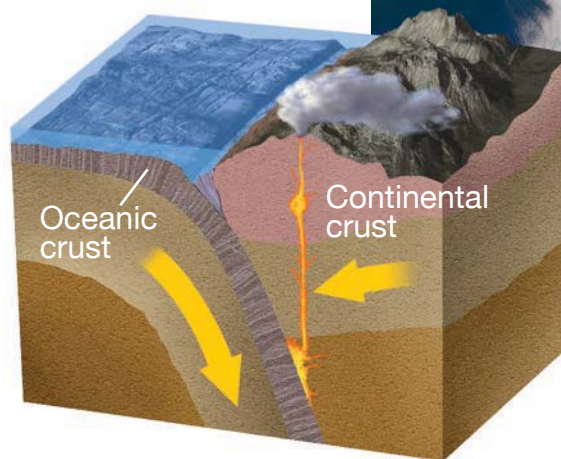
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○ At Convergent Boundaries

At convergent boundaries, two plates move toward each other. In most cases, one plate sinks beneath the other plate. As the sinking plate dives into the mantle, fluids in the sinking plate become super heated and escape. These escaping fluids cause the rock above the sinking plate to melt and form magma. This magma rises to the surface and erupts to form volcanoes.

The magma that forms at convergent boundaries has a high concentration of fluids. As the magma rises, decreasing pressure causes the fluid trapped in the magma to form gas bubbles. But, because the magma has a high viscosity, these bubbles cannot escape easily. As the bubbles expand, the magma rises faster. Eventually, the magma can erupt explosively, forming calderas or composite volcanoes. Gas, ash, and large chunks of rock can be blown out of the volcanoes. The Cascade Range is a chain of active composite volcanoes in the northwestern United States, as shown to the right. In 1980, Mt. St. Helens erupted so violently that the entire top of the mountain was blown away.

Tectonic plates move toward each other at convergent boundaries.



👁 Visualize It!

12 Identify Draw two arrows in the white boxes to indicate the direction of motion of the plates that formed the Cascade volcanoes.



13 Summarize List the characteristics of divergent-boundary volcanoes and convergent-boundary volcanoes below.

Volcanoes at divergent boundaries	Volcanoes at convergent boundaries

At Hot Spots

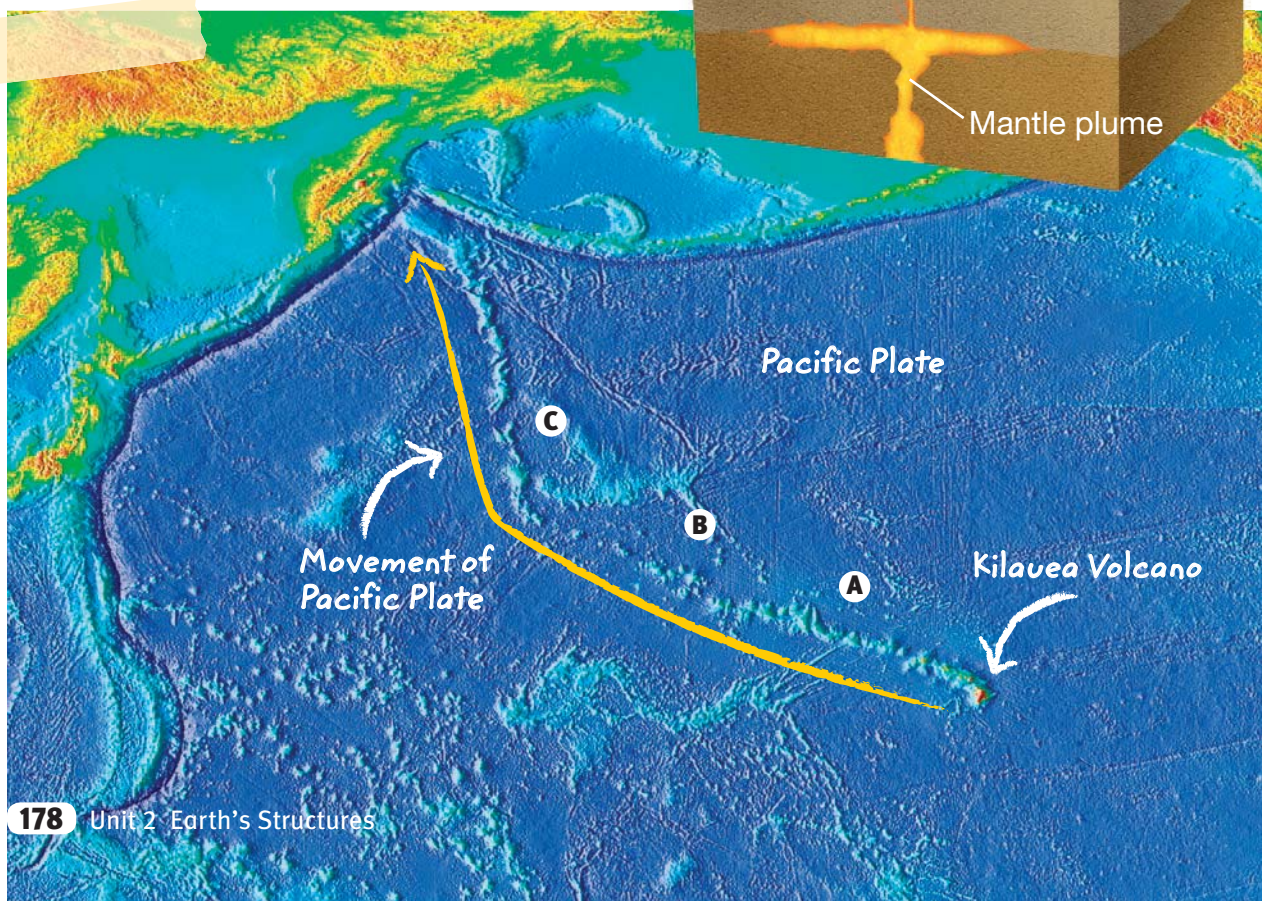
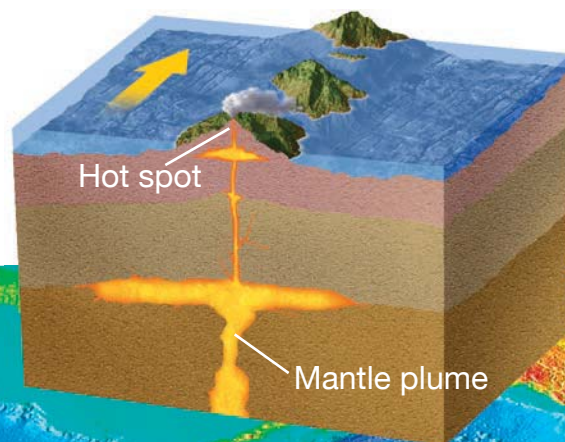
Volcanoes can form within a plate, away from the plate boundaries. A **hot spot** is a location where a column of extremely hot mantle rock, called a *mantle plume*, rises through the asthenosphere. As the hot rock reaches the base of the lithosphere, it melts partially to form magma that can rise to the surface and form a volcano. Eruptions at a hot spot commonly form shield volcanoes. As tectonic plates move over a mantle plume, chains of volcanic mountains can form, as shown below.

The youngest Hawaiian island, the Big Island, is home to Kilauea (kih•loh•AY•uh). The Kilauea volcano is an active shield volcano located over a mantle plume. To the north and west of Kilauea is a chain of progressively-older shield volcanoes. These volcanoes were once located over the same mantle plume. Hot spots can also occur on land. Yellowstone National Park, for example, contains a huge volcanic caldera that was formed by the same mantle plume that created the Columbia Plateau.

Visualize It!

- 14 Claims • Evidence • Reasoning** Make a claim about which location, A, B, or C, is the oldest volcano. Give evidence to support the claim and explain your reasoning.

Hot spots form over mantle plumes within a tectonic plate.

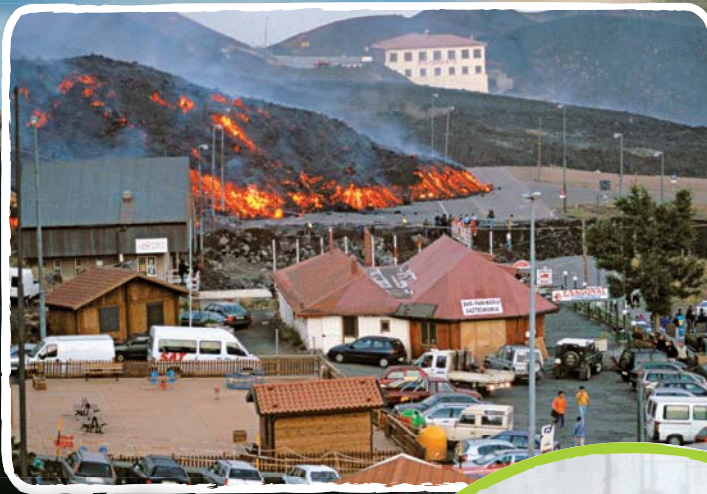


WHY IT MATTERS

Living Near a Volcano

EYE ON THE ENVIRONMENT

Volcanoes occur around the world. Many people live near volcanoes because the soils around a volcano can be very rich with essential minerals. These minerals make the soils fertile for growing a variety of crops. Living near a volcano also has its hazards. Sudden and unexpected eruptions can cause people to lose their homes and their lives.



Destruction
Earthquakes, fires, ash, and lava flows during an eruption can destroy entire cities.



Ash in the Air
Volcanic ash can cause breathing problems, bury crops, and damage engines. The weight of falling ash can cause buildings to collapse.

Not All Bad
Volcanic rocks are used in jewelry, in making concrete, and in water filtration systems. Even cat litter and facial scrubs can contain volcanic rock.

i Extend

15 Claims • Evidence • Reasoning Make a claim about whether all characteristics of volcanoes are dangerous. Summarize evidence to support the claim and explain your reasoning.

16 Apply Research the eruption of a specific volcano of your choice. Describe how the

volcano affected the environment and the people near the volcano.

17 Design Create a poster that outlines a school safety plan for events that can occur before, during, and after a volcanic eruption.

Visual Summary

To complete this summary, check the box that indicates true or false. You can use this page to review the main concepts of the lesson.

Lava and magma are different.



- 18 Lava is inside Earth's crust and may contain trapped gases.

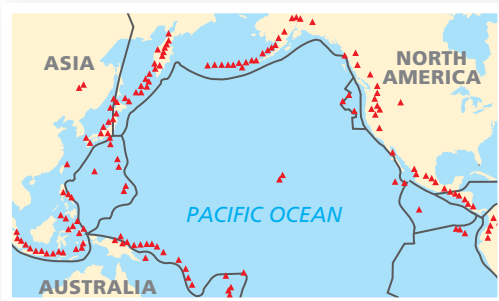
The three types of volcanic mountains are shield volcanoes, cinder cones, and composite volcanoes.



- 19 The type of volcano shown is a shield volcano.

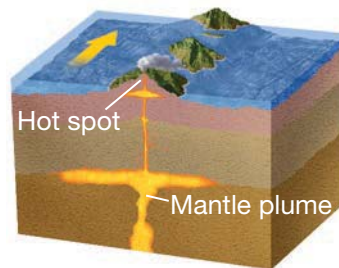
Volcanoes

Volcanoes can form at tectonic plate boundaries.



- 20 At divergent plate boundaries, plates move toward each other.

Volcanoes can form at hot spots.



- 21 Hot spots are restricted to tectonic plate boundaries.

22 Claims • Evidence • Reasoning Make a claim about how volcanoes contribute to the formation of new landforms. Summarize evidence to support the claim and explain your reasoning.

Vocabulary

Write 1 or 2 sentences that describe the differences between the two terms.

1 magma lava

2 volcano vent

3 tectonic plate hot spot

Key Concepts

Use the image to answer the following question.



4 Identify How did the composite volcano in the image get its layered interior?

5 Analyze Is pyroclastic material likely to form from low-viscosity lava or high-viscosity lava? Explain your answer.

Describe the location and characteristics of the types of volcanic landforms in the table below.

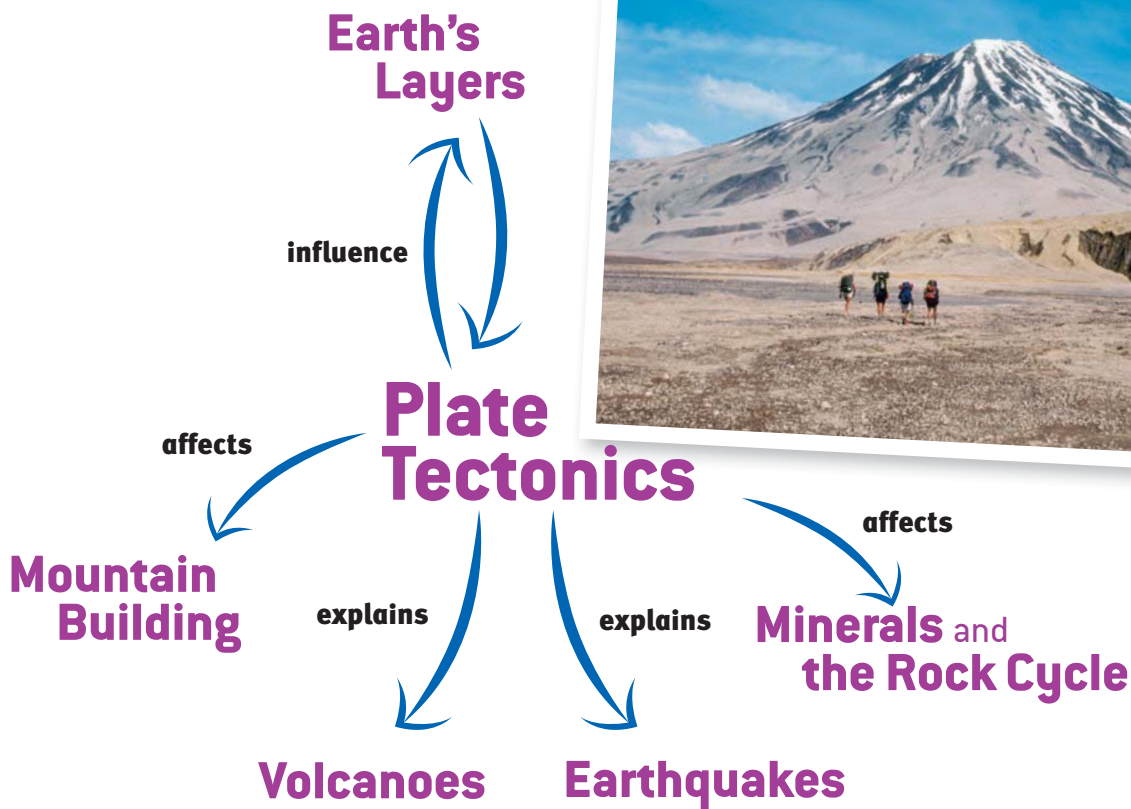
Volcanic landform	Description
6 Hot-spot volcanoes	
7 Cinder cones	
8 Calderas	

Critical Thinking

9 Claims • Evidence • Reasoning In Iceland, the Mid-Atlantic Ridge runs through the center of the country. Make a claim about the appearance of Iceland many thousands of years from now. Summarize evidence to support the claim and explain your reasoning.

10 Analyze Why do you think the location surrounding the Pacific Ocean is known as the Ring of Fire?

UNIT 2 Summary



1 Claims • Evidence • Reasoning The Graphic Organizer above shows how Earth's surface changes because of Earth's layers. Make a claim about changes on a planet that has the same composition from core to surface. Use evidence to support the claim and explain your reasoning.

2 Relate How are Earth's crust and mantle involved in the formation of new rock?

3 Apply Explain how a volcanologist can piece together the history of a volcano by studying the rock that makes up the volcano.



Name _____

Vocabulary

Fill in each blank with the term that best completes the following sentences.

- 1 The hot, convecting _____ is the layer of rock between the Earth's crust and core.
- 2 _____ is the theory that explains how large pieces of Earth's outermost layer move and change shape.
- 3 _____ is the bending of rock layers due to stress.
- 4 A(n) _____ is a vent or fissure in the Earth's surface through which magma and gases are expelled.
- 5 A(n) _____ is a movement or trembling of the ground that is caused by a sudden release of energy when rocks move along a fault.

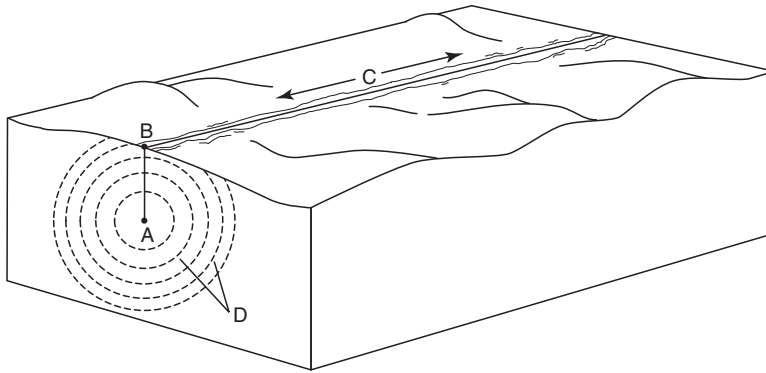
Key Concepts

Identify the choice that best completes the statement or answers the question.

- 6 One way of measuring the amount of energy released by an earthquake is the Richter scale. Each increase of one unit on the Richter scale shows a 10-fold increase in the strength of the earthquake. What determines how strong an earthquake will be?
 - A distance from the epicenter of the earthquake
 - B amount of stress released by the elastic rebound of rock
 - C the temperature of the rock just before the earthquake begins
 - D the density of population and buildings near the epicenter of the earthquake
- 7 Earth's core is composed of two separate layers: the inner core and the outer core. What is one difference between these two layers?
 - F One is iron, and one is zinc.
 - G One is liquid, and one is gas.
 - H One is solid, and one is liquid.
 - I One is iron, and one is nickel.

- 8** Scientists study different parts of earthquakes and how they are related. This illustration shows a cross section of the lithosphere when an earthquake is taking place.

Cross Section of Lithosphere during an Earthquake



Where is the epicenter of this earthquake located?

- A** point A
 - B** point B
 - C** along the line labeled C
 - D** along the line between points A and B
- 9** Convection currents in the mantle contribute to tectonic plate movement. What is a convection current?
- F** the transfer of energy through materials in direct contact
 - G** the transfer of energy due to the movement of matter
 - H** the transfer of energy as electromagnetic waves
 - I** the transfer of energy from a region of lower temperature to a region of higher temperature
- 10** Granite forms when liquid magma slowly cools within Earth's crust. If the granite is exposed to intense heat and pressure, it can change to gneiss. Which type of change takes place when granite turns into gneiss?
- A** Sedimentary rock changes into igneous rock.
 - B** Igneous rock changes into metamorphic rock.
 - C** Metamorphic rock changes into igneous rock.
 - D** Sedimentary rock changes into metamorphic rock.

16 Quartz, feldspar, and mica are silicate minerals. Silicate minerals contain atoms of silicon and oxygen and often other elements bonded together. What must be **true** of silicate minerals?

- A** They are pure elements.
- B** They are made up of compounds.
- C** They melt at very low temperatures.
- D** They are made up of only one kind of atom.

17 The following steps are part of a laboratory exercise that Florida sixth-grade students are doing in their science class.

Step	Procedure
1	Get an ice cube that has been darkly colored with food coloring.
2	Use tongs to place the ice cube in a beaker containing warm water. Be sure to lower the ice cube slowly to keep the water as still as possible.
3	Observe the ice cube and water mixture for at least 5 min.

What are these students modeling?

- F** plate boundary
- H** movement of tectonic plates
- G** continental drift
- I** convection currents in the mantle

18 Mr. Garcia told his seventh-grade class that as a tectonic plate moves farther from a mid-ocean ridge, it cools and becomes denser. This can cause the plate to sink below another, less dense tectonic plate. The weight of the sinking plate then drags the rest of the plate downward. What is Mr. Garcia describing?

- A** slab pull
- C** continental drift
- B** ridge push
- D** convection current

22 Mount Everest formed when two tectonic plates collided. Which process then took place to create Mount Everest?

- A** erosion
- B** subsidence
- C** uplift
- D** weathering

Critical Thinking

Answer the following questions in the space provided.

23 Explain how a convergent boundary is different from a transform boundary.

Then name one thing that commonly occurs along both convergent boundaries and transform boundaries.

24 The diagram below shows the five physical layers of Earth.

Identify the physical layers A, B, and C. Is the relationship between these layers important to understanding plate tectonics? Use evidence to support your claim and explain your reasoning.

