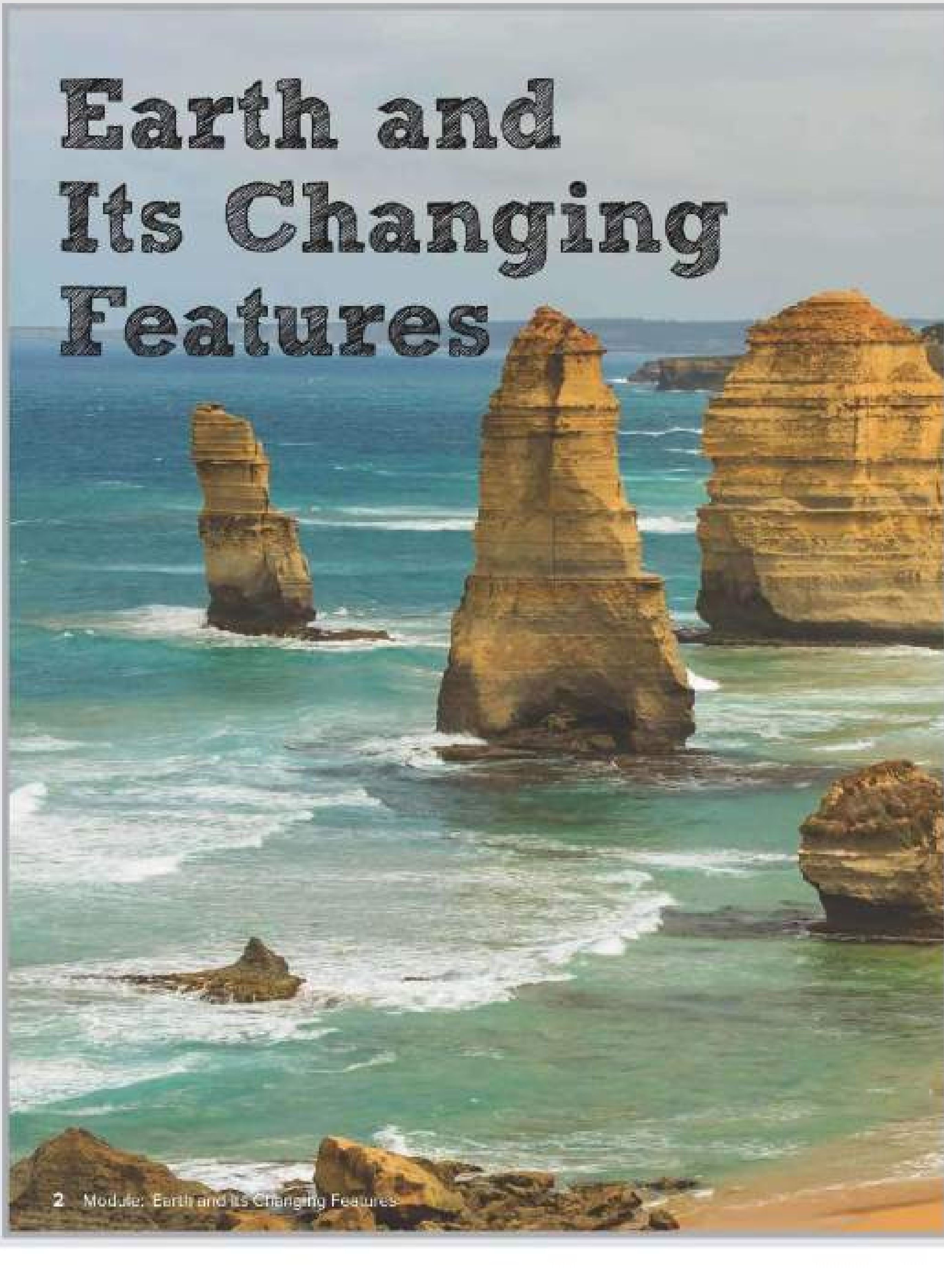
Earth and Its Changing Features



ENCOUNTER
THE PHENOMENON

How were these land features formed?

GO ONLINE
Check out *Twelve Apostles* to see the phenomenon in action.

Talk About It

Look at the photo and watch the video of the rock pillars in the water. What do you observe? Talk about your questions with a partner.

Did You Know?

Only 8 of the 12 pillars of the famous Twelve Apostles are still standing today.

STEM Module Project Launch

Engineering Challenge

Don't Get Carried Away

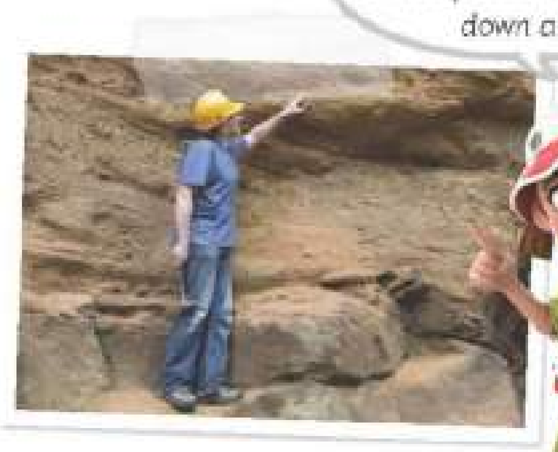
How do wind, water, and ice affect the land? How can you slow the rate at which rock and soil are carried away? You are being hired as a geologist. You goal is to design two models to solve the problem created when rocks and soil are carried downhill. Test and compare multiple solutions to reduce the impact of erosion on humans. For each model, include a map to identify areas that are too hazardous for building structures. Determine the criteria, constraints, and materials that will be used to complete your project.

Lesson 1
Map Earth's Features

Lesson 2
Evidence from Rocks and Fossils

Lesson 3
Changes in Landscapes Over Time

Find multiple solutions to stop soil from moving down a hill.



Geologists study what makes up Earth and the processes that change it. They study and map areas that might be at risk of landslides and other hazards.

MAYA
Geologist

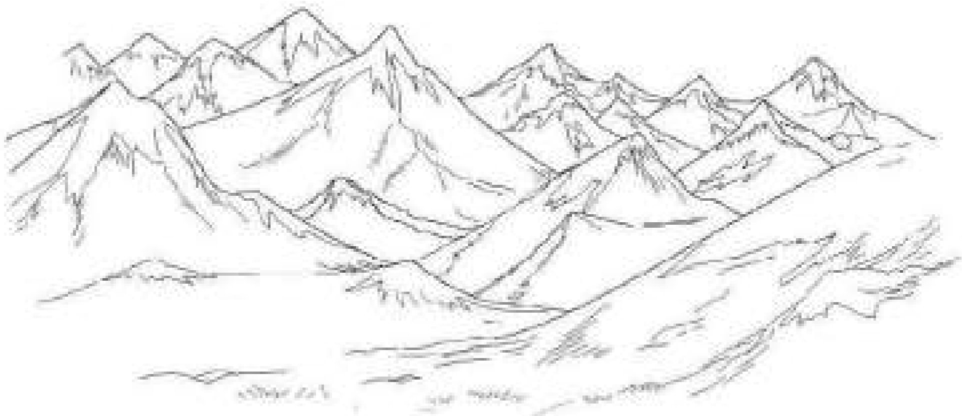
STEM Module Project

Plan and Complete the Engineering Challenge You will use what you learn to design and compare solutions for soil erosion.

PAGE KEELEY SCIENCE PROBES

LESSON 1 LAUNCH

Land and Water Features



Four friends were talking about land and water features such as mountain ranges, volcanoes, ocean trenches, and formations on the ocean floor. They wondered which features occur in patterns. This is what they said:

Woojin: *I think the features on land are the ones that occur in patterns.*

Noah: *I think the features found in oceans are the ones that occur in patterns.*

Abby: *I think both the land and ocean features occur in patterns.*

Elena: *I think land and ocean features occur anywhere. They don't follow any patterns.*

Whom do you agree with most? Abby

Explain why you agree.

Sample answer: Land and water features both follow patterns based on where they are found on Earth.

You will revisit the Page Keeley Science Probe later in the lesson.

LESSON 1

Map Earth's Features

ENCOUNTER
THE PHENOMENON

What patterns can you find in the locations of Earth's features?

GO ONLINE

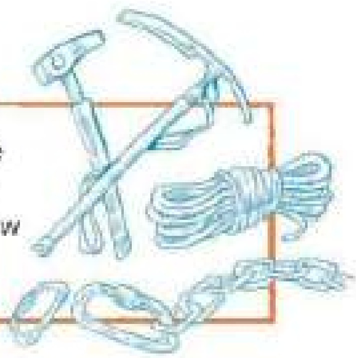
Check out *Land Features* to see the phenomenon in action.

Look at the photo and watch the video of different landscapes across the continental United States. What do you observe? What do you wonder about the map? Write your observations below.

Sample answer: Why is the map shaded in multiple colors? Do other countries have similar patterns? Where are most of the mountains located in the United States?

Did You Know?

Denali, Alaska is the highest elevation in the United States at 6,190 meters (20,310 feet) above sea level. Temperatures can dip as low as -60°C (-75°F).



INQUIRY ACTIVITY

Hands On

Map California's Features

Think about the land in your town. Now think about the land in other parts of California. You will design and construct a three-dimensional map of California.

Make a Prediction What landscape features will be important to show in the 3-D model of a California map?

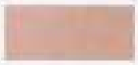
Sample answer: I think the location and height of different features will be important to show in my model.

Carry Out an Investigation

BE CAREFUL Do not eat any of the materials used for this investigation.

1. Glue the outline of California to the sheet of cardboard.
2. Use the spoon and your hands to mix the flour, salt, and water in the bowl. The mixture should make a dough that is easily shaped. If it is still runny after mixing, ask your teacher for more salt and flour.
3. Place the dough on the cardboard and flatten it out to the edges of your outline of California.

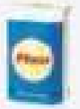
Materials


sheet of cardboard (20 x 30 cm)


California outline photocopy


glue


measuring cup



2 cups flour


bowl

1 cup salt


¾ cup water


spoon


permanent markers

4. Use the dough to make landforms in the correct locations. See the map below for reference.

5. Let the dough dry overnight.

> **GO ONLINE** Use the Personal Tutor *Real-World Example: Use Proportions to Solve Problems* to practice how to express a larger unit in terms of a smaller unit.

6. Label major features on your 3-D map, including cities, mountains, valleys, and bodies of water. Use the teacher-approved websites for help with identifying these features.

INQUIRY ACTIVITY

Communicate Information

7. Where are the low areas on your map? How can you tell?

Sample answer: The central part of California, between the Sierra Nevada and the Coast Range, has low elevations. This area is known as the Great Valley. Death Valley and the Colorado Desert near the southern end of California also have very low elevations. These areas were the lowest on my map.

8. Where are the high areas on your map? How can you tell?

Sample answer: The Sierra Nevadas and the Coast Range are mountains. They are the highest areas on my map.

9. How did you use the dough and markers to represent different features? Was your prediction supported by your observations?

Sample answer: I made the dough taller or flatter to represent different features. I also used the markers to label things and to help show where oceans and lakes are. I used blue for the ocean and green for the land. My prediction was supported.

10. **MATH Connection** A group of hikers set up camp at an elevation of 2 km above sea level. How many meters are they above sea level? Show your work.

Since 1 kilometer = 1000 m, then
2 x 1,000 = 2,000 m

MAKE YOUR CLAIM

Think of the model you created. What patterns did you notice in the locations of mountains?

Make your claim. Use your investigation.

CLAIM

Most of the mountains in the continental Unites States are located ______________

Sample answer: in the West and Southwest regions.

Cite evidence from the lesson.

EVIDENCE

The investigation showed that ______________________________

Sample answer: most of the mountains occurred in bands along the west coast of the continental U.S. where two plates meet.

Discuss your reasoning as a class. Tell about your discussion.

REASONING

The evidence supports the claim because ______________________________

Sample answer: Earth's forces caused plates to push or pass each other in areas known as plate boundaries resulting in mountain ranges.

You will revisit your claim to add more evidence later in this lesson.

VOCABULARY

Look for these words as you read:

- continent
- earthquake
- landform
- latitude
- longitude
- plate
- topographic map
- volcano

Landforms

In the Inquiry Activity, *Map California's Features*, you represented different landforms on a three-dimensional map. A **landform** is a physical feature on Earth's surface. Landforms vary greatly in shape and size. They include features such as level plains, rounded hills, and jagged mountains. Each landform has specific characteristics and is formed in a specific way.

Label a Diagram: Earth's Land and Water Features

Use the labels on the image below and descriptions on the next page to learn more about common landforms. Fill in the missing labels using the descriptions.

GO ONLINE Watch the video *Landforms* to see various landforms around the world.

Mountain A landform that rises high above the Earth's surface.

Hill A natural elevation of the Earth's surface, smaller than a mountain.

Valley A valley is the low land between hills or mountains.

Canyon A canyon is a deep valley with high, steep sides.

Plain A plain is a wide, flat area.

Plateau A plateau is flat land that is higher than the land around it.

Desert A desert is an area with very little precipitation.

Beach A beach is the land along the edge of a body of water.

Dune A dune is a mound of sand.

Ocean An ocean is a large body of salt water.

Coast A coast is where a body of water meets land.

River A river is a natural body of moving water.

Lake A lake is a body of water surrounded by land.

Delta A delta is the mass of land that forms at the mouth of a river.

Inlet An inlet is a narrow body of water off a larger body of water.

1. What landforms are near you?

Sample answer: Some landforms that are near me are mountains, valleys, and plains.

Earth's Ocean Features

Oceans are large bodies of salt water. They make up more than 70 percent of Earth's surface. If you could travel deep below the ocean's surface, you would find features on the ocean floor that look like the mountains, plains, and valleys on Earth's surface.

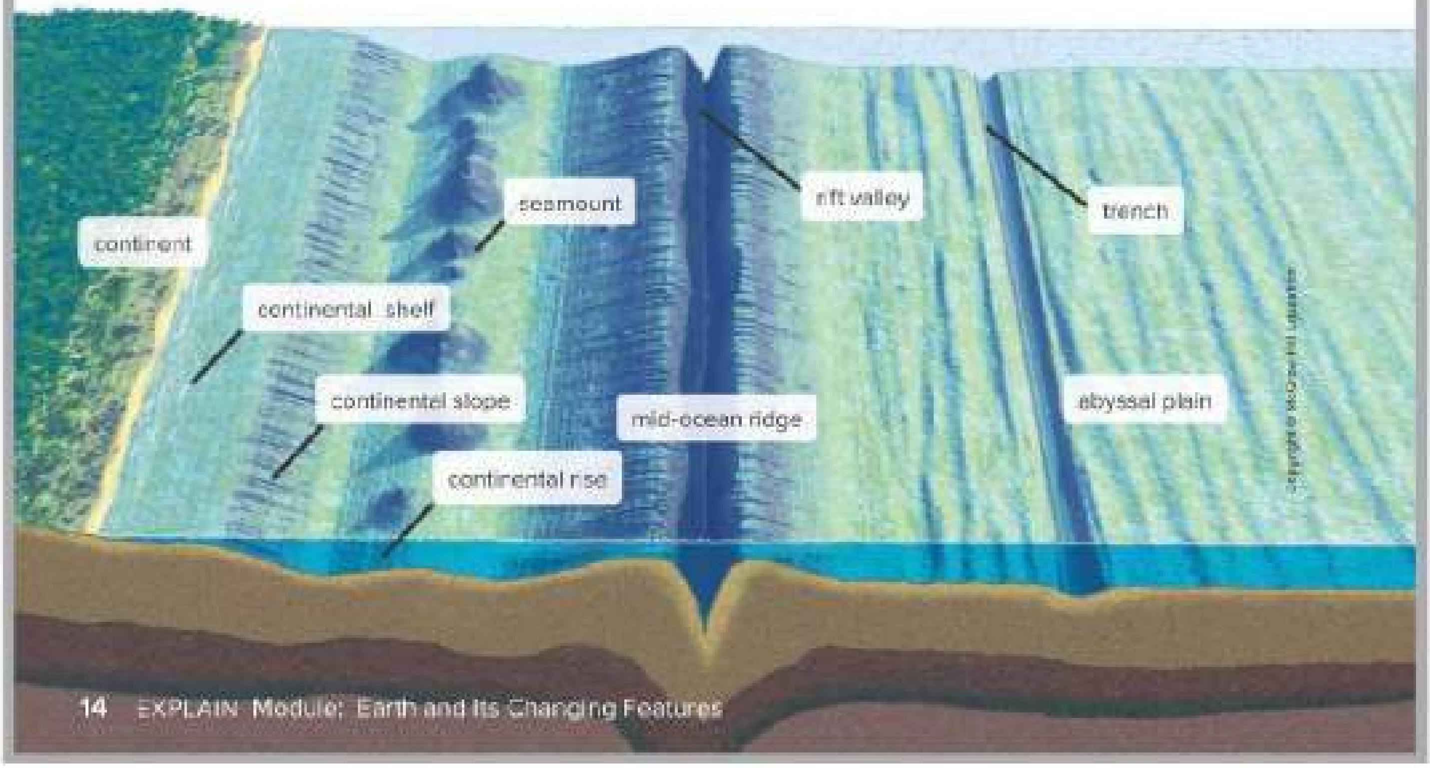
A **continent** is a large landmass. Along the coast of a continent, the ocean floor is called the *continental shelf*. Here, the ocean floor is covered by shallow water and gradually slopes down. The continental shelf ends at the point where a sharp downward slope begins. This is called the *continental slope*. This land is the steeper part of the continent that slopes down toward the ocean floor. Underwater canyons can form on the continental slope.

At the base of the continental slope is the *continental rise*. The continental rise connects the continent with the ocean floor.

1. What is the flattest part of the ocean floor?

The abyssal plain is the flattest part of the ocean.

Ocean Features



Most of the ocean floor is flat and without features. An abyssal plain is a very flat area of the deep ocean floor. These plains cover about 60 percent of the Earth's surface.

GO ONLINE Watch the video *Ocean Floor* to learn more about these features.

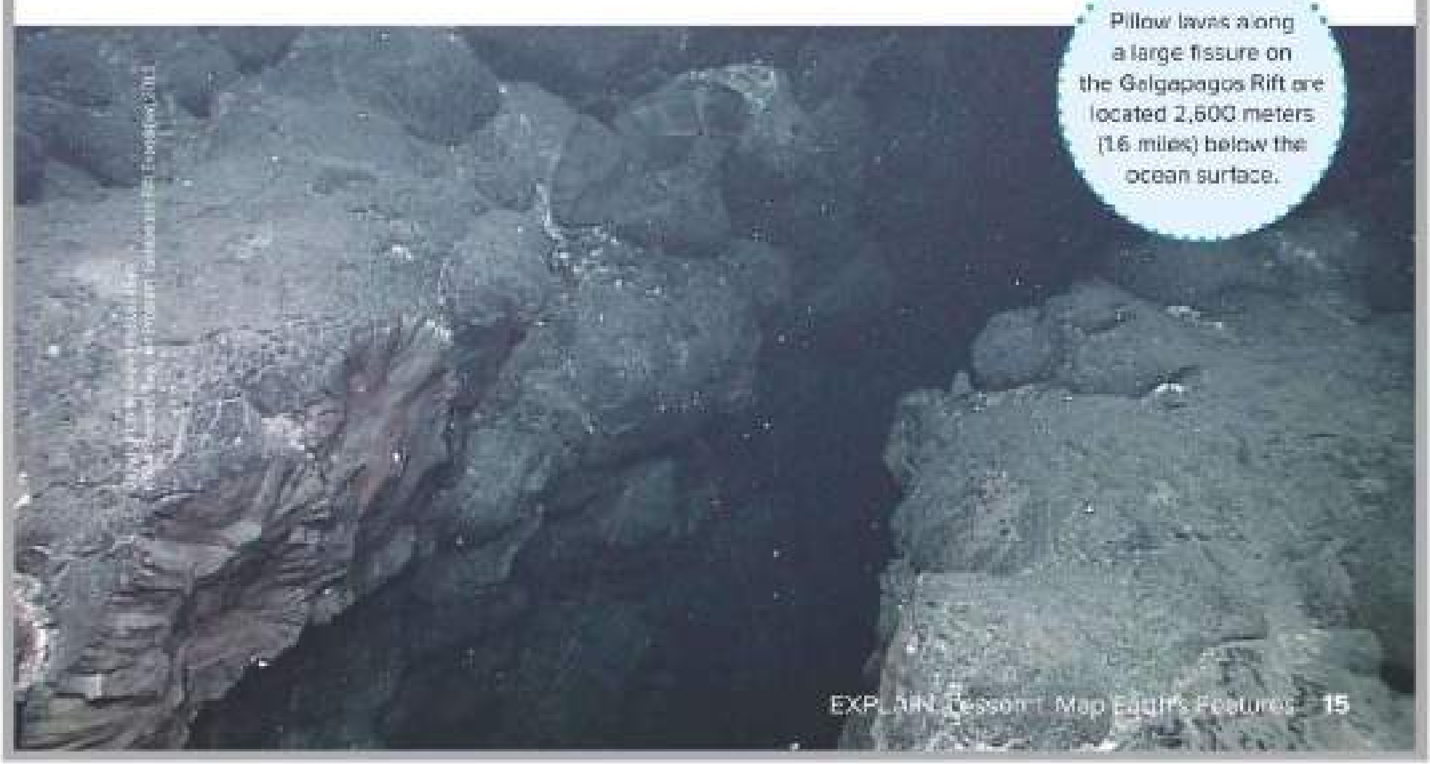
Long mountain ranges stretch through the middle of some oceans. These mountain ranges are called *mid-ocean ridges*. The valley down the center of a mid-ocean ridge is called a *rift valley*.

Other ocean floor features include trenches and seamounts. *Trenches* are the deepest parts of the ocean floor. They are usually long and narrow. A *seamount* is an underwater mountain that rises from the ocean floor but stops before it reaches the surface of the ocean.

Scientists can tell the depth of the ocean floor by sending sounds and waiting for the echo to come back. They also use underwater vehicles to study the ocean floor.

2. Which ocean floor features are underwater mountains?

Sample answer: Mid-ocean ridges and seamounts are both examples of ocean floor features.



Pillow lavas along a large fissure on the Galgapagos Rift are located 2,600 meters (1.6 miles) below the ocean surface.

Map Earth's Features

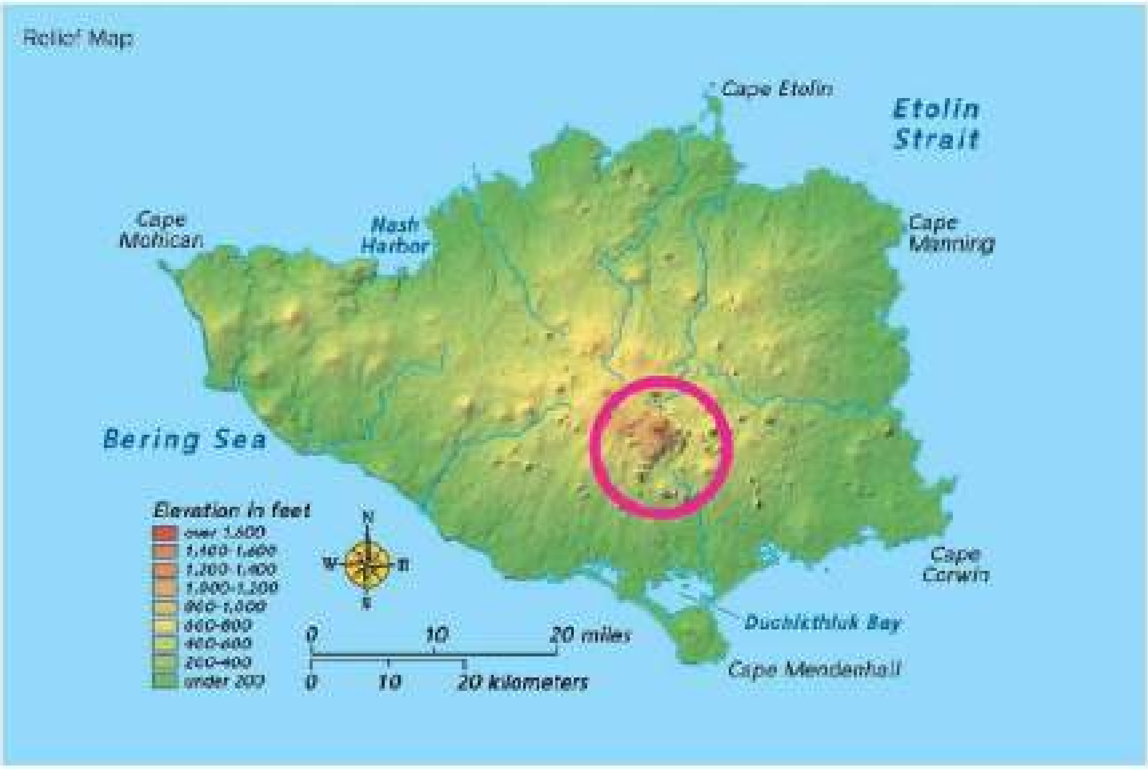
> **GO ONLINE** Explore *Map California* to analyze the patterns and features of California's landscape.

As you have learned, Earth's surface is uneven. Hills rise in one location, and valleys dip in another. The map that you made in the Inquiry Activity, *Map California's Features*, was not flat, but most maps of Earth's surface are. How can a flat map show an uneven surface?

There are many different kinds of maps. Physical maps show the features of Earth's land and water. Mountains, deserts, and plains are often shown on physical maps. Some physical maps use shading or lines to represent changes in elevation. *Elevation* is the height of the land above sea level. A map that uses shading to show elevations is called a *relief map*. Relief maps can also reveal patterns in an area.

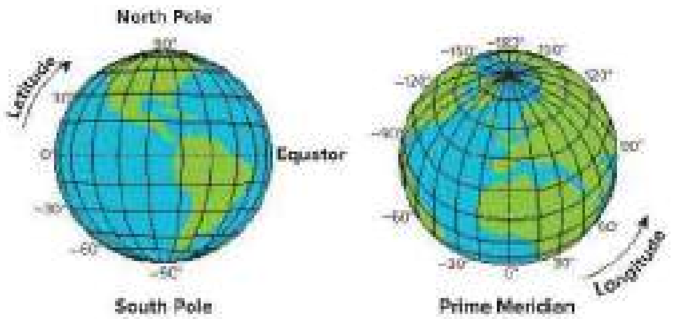
Read a Map: Nunivak Island, Alaska

Using the key, circle the highest part of Nunivak Island on the relief map below.

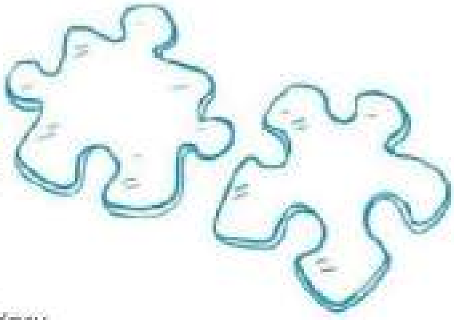


A **topographic map** shows the elevation of an area using lines. Each line is labeled with a number. Contour lines that are close together represent a rapid change in elevation. Contour lines that are far apart represent a gradual change in elevation.

Scientists can use maps to identify patterns in the locations of landforms and other features. The locations of certain features can be described using a coordinate system such as latitude and longitude. **Latitude** is used to describe how far north or south a place is from the equator. **Longitude** is used to describe how far east or west a place is from the Prime Meridian. Latitude and longitude lines form a grid across the globe.



Our Puzzle Planet



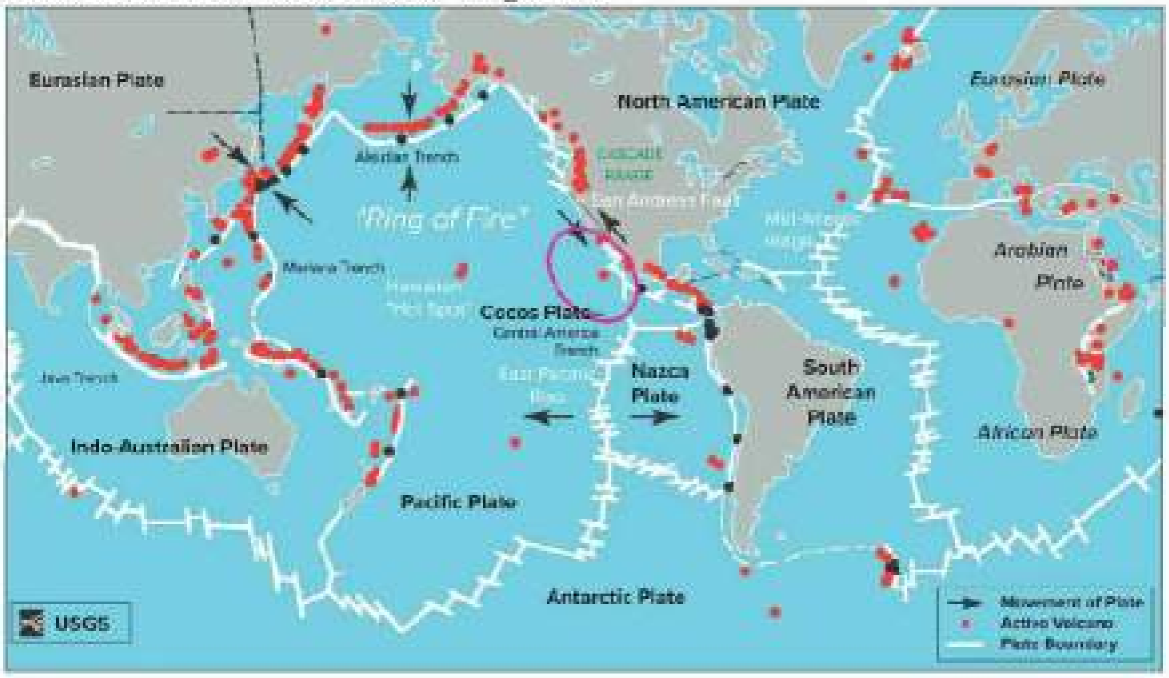
Earth has an outer layer of solid rock called the crust. The crust is broken into very large pieces called **plates**. The plates fit together like the pieces of a jigsaw puzzle. They move over a layer of hot, almost-melted rock that can flow. Earth's plates move like big, floating rafts on a lake. They move together, apart, and past each other. The place where two plates meet is called a *plate boundary*.

Earth's continents and oceans cover these plates. The plates creep along very slowly. Usually, you cannot tell they are moving.

Read a Map

1. Circle the area where two plates are moving past each other.

Active Volcanoes, Plates, and the "Ring of Fire"



COLLECT EVIDENCE

Use the map to add evidence to your claim on page 11.

REVISIT Revisit the Page Keeley Science Probe on page 5.

PAGE KEELEY SCIENCE PROBES

Tension, or forces that pull things apart, moves Earth's plates. Plates can also be moved by pushing forces. Mountains form when plates push together or past each other along plate boundaries. Many earthquakes and volcanoes also happen at plate boundaries.

A **volcano** is an opening on Earth's surface where melted rock or gases are forced out. Volcanoes can form on land or on the ocean floor, but they are located only in certain places on Earth's surface. Most volcanoes form at plate boundaries. For example, a ring of volcanoes called the *Ring of Fire* surrounds the Pacific Ocean. The Ring of Fire follows the boundaries of the plates that meet around the Pacific Ocean.

An **earthquake** is a sudden movement of Earth's crust. Like volcanoes, most earthquakes occur because of moving plates. Also, like volcanoes, earthquakes are most likely to occur near plate boundaries. You will learn more about earthquakes in the next module.

2. Describe the global patterns of volcanoes and earthquakes that are shown on the world map.

Both are likely to occur near plate boundaries.

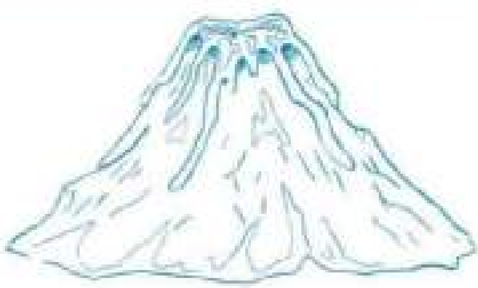
Think about the ocean floor features from page 14. Some of these features, like ocean trenches, occur where two plates push together. Mid-ocean ridges occur where two plates spread apart. As the two plates move apart, new crust forms. The mid-ocean ridges are all connected and form the most extensive underwater mountain sytem on Earth.

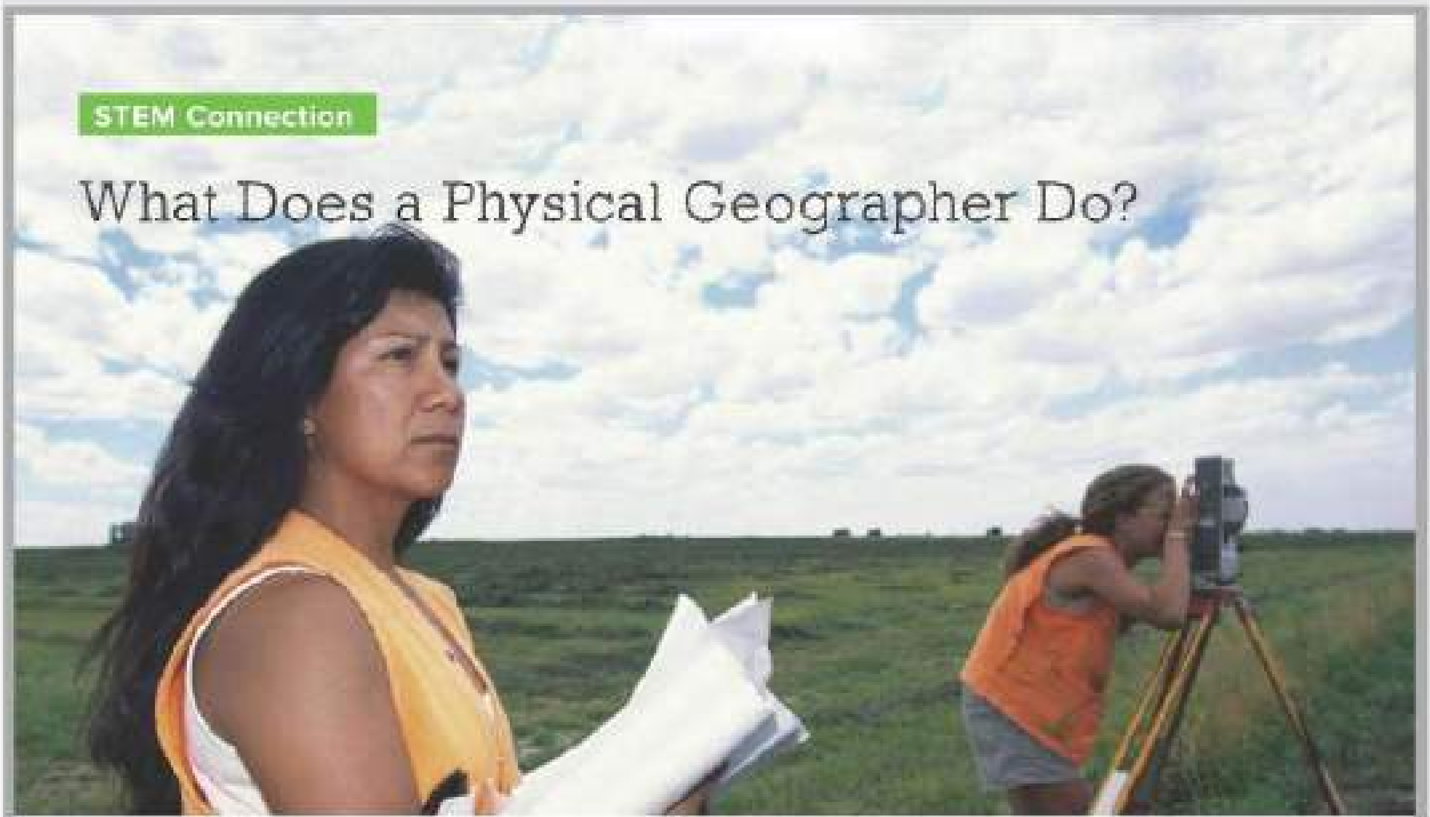
3. Use the graphic organizer to classify the location of the following features: abyssal plains, earthquakes, mountains, volcanoes.

Near Plate Boundaries	Not Near Plate Boundaries
earthquakes, mountains, volcanoes	abyssal plains

Talk About It

Explain to a classmate where you would most likely find mountain ranges on the ocean floor.





STEM Connection

What Does a Physical Geographer Do?

Physical geographers use physical maps to look for patterns in climate data, soil type, or water distribution. They might also look for patterns in the locations of certain types of landforms or natural hazards, such as earthquakes or volcanic eruptions.

Long ago, physical geographers used paper maps to plot data, and make measurements. Today, they use several different technologies to make their work more efficient. Global positioning systems (GPS), remote sensing, and online mapping tools are a few of these technologies. GPS uses satellites to generate accurate location information. Remote sensing uses satellites or aircraft to get information about Earth from a distance.

It's Your Turn

Now you will make your own map. Like a physical geographer, you will use it to describe the location and shape of a model landform.

INQUIRY ACTIVITY

Hands On

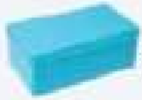
Map the Ocean Floor

Have you ever been on a boat and wondered how deep the water was? We cannot see most parts of the ocean floor, but we know that scientists use different tools to measure underwater landforms and create topographic maps.

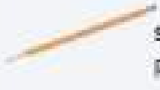
State the Claim How can depth measurements be used to make a map of something that cannot be seen?

Sample answer: I can plot the depth measurements on a grid and use lines to connect similar depths.

Materials



shoebox



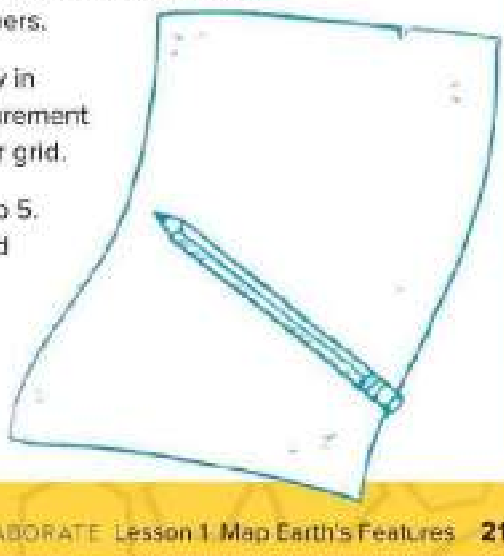
sharpened pencil

drinking straw

ruler

Carry Out an Investigation

1. Use the ruler to make horizontal lines across the box every 2 centimeters and vertical lines every 2 centimeters.
2. Use a sharpened pencil to poke a hole through the box at every intersection of the horizontal and vertical lines. The hole should be large enough for the straw to fit through.
3. Draw a grid on the next page to match the grid on the shoebox.
4. Label each of the vertical lines on both grids with letters. Label each of the horizontal lines on both grids with numbers.
5. **Record Data** Gently drop the measuring straw in point A1 on your grid. Record the depth measurement of the straw, to the nearest centimeter, on your grid.
6. Move to point A2 on your grid, and repeat step 5. Continue this process until you have measured the depth at each hole.



INQUIRY ACTIVITY

7. Use your probe measurements to figure out the height of the clay in each hole. Record the height on the grid below.
8. Take a look at the data. How can you use the data to create a map of the landform? Discuss your ideas with a partner.

9. Remove the lid and compare your drawing to the landform in the box.

Sample answer: My map was similar to the landform in the box, but it was missing some of the details.

Communicate Information

10. How did you use your depth measurements to calculate the height of the landform?

Sample answer: I measured the depth of the box and then subtracted my straw measurement to determine the landform height.

11. How did you use depth measurements to make a map? Use evidence to support your claim.

Sample answer: I plotted the depth measurements on a labeled grid. Then I connected equal depth measurements using contour lines. This created a topographic map of the landform.

Analyze and interpret data to describe how the shape of the clay landform compares to your **model**. What **patterns** do you see?

Sample answer: The overall shape was pretty similar to my map, but there were some details that weren't captured by my map since the measurements were only taken every 2 cm.

LESSON 1

Review

EXPLAIN
THE PHENOMENON

What patterns can you find in the locations of Earth's features?

Summarize It

Describe the patterns in the locations of Earth's features, such as mountains, ocean floor structures, volcanoes, and earthquakes.

Sample answer: Mountains tend to be found along the edges of continents at plate boundaries. Underwater mountain ranges occur where two plates move apart. Volcanoes and earthquakes are most likely to occur near two plates that are pushing together, along the boundaries between continents and oceans.

REVISIT PAGE KEELEY SCIENCE PROBES

Revisit the Page Keeley Science Probe on page 5. Has your thinking changed? If so, explain how it has changed.

Three-Dimensional Thinking

1. Which feature is most likely to occur near the edge of a continent?

   A. plain

   B. mountain

   C. lake

   D. abyssal plain

2. Where would you most likely find volcanoes?

   Sample answer: Volcanoes are usually found near two plates that are pushing together.

3. Observe the photo above. What ocean features can be mostly found away from plate boundaries?

   A. trenches

   B. seamounts

   C. mid-ocean ridges

   D. abyssal plains

Extend It

You learned that physical geographers use different types of technology for mapping, including global positioning systems (GPS) and remote sensing. Choose a technology and make a television news report explaining how it is used to find patterns. Outline your news report below.

Sample answer: Good evening viewers. Welcome to our special science news edition. Engineers at the National Oceanic and Atmospheric Administration (NOAA) have designed a new technology that will change how we map landforms. The new technology uses remote sensing to detect energy emitted from Earth. The sensors interpret the data and then provide an image. Sensors can be placed on planes or satellites.

OPEN INQUIRY

What questions do you still have about how Earth's features are mapped?

Sample answer: What other types of technologies can be used to map the ocean floor?

Plan and carry out an investigation or research to find the answer to your question.

KEEP PLANNING

STEM Module Project

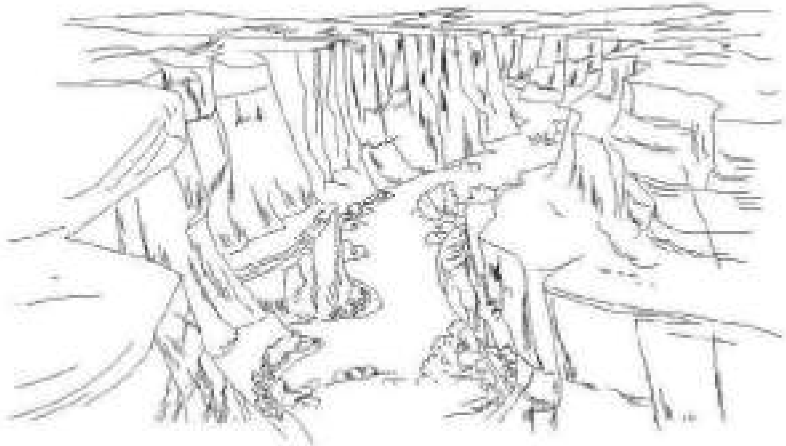
Engineering Challenge

Now that you have learned about Earth's features and how they are mapped, go to your Module Project to explain how the information will affect your model.

PAGE KEELEY SCIENCE PROBES

LESSON 2 LAUNCH

Information from Layers of Rock



Four friends were looking at the layers of rock in a canyon. They each had different ideas about what scientists learn by examining the rock layers. This is what they said:

Anita: *I think scientists examine rock layers to learn about organisms that lived in the past.*

Mason: *I think scientists examine rock layers to learn about how the surface of the Earth changes over time.*

Aaron: *I think scientists examine rock layers to learn about organisms that lived in the past and how the surface of the Earth has changed.*

Owen: *I don't think rock layers help scientists learn about organisms that lived in the past or how the surface of the Earth has changed. They examine rock layers to identify rocks and minerals.*

Whom do you agree with most? Aaron

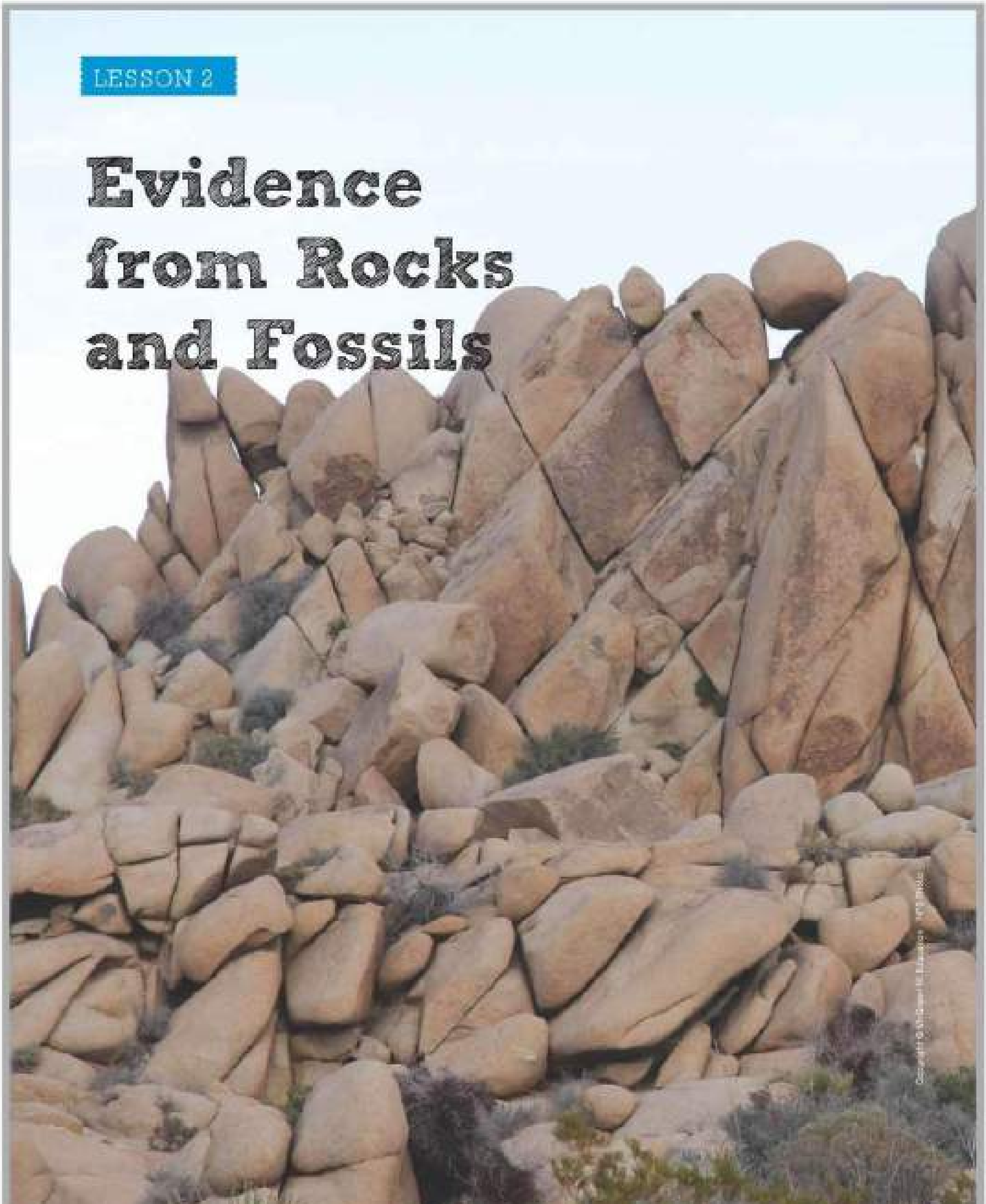
Explain why you agree.

Sample answer: Scientists can learn about Earth's history from fossils and from the type of rock found in a formation.

You will revisit the Page Keeley Science Probe later in the lesson.

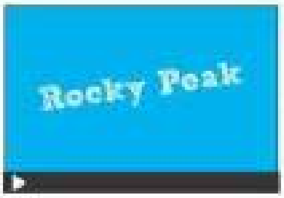
LESSON 2

Evidence from Rocks and Fossils



ENCOUNTER
THE PHENOMENON

What information can we get from rocks?



GO ONLINE

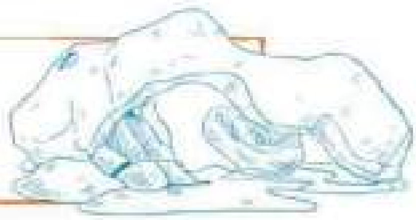
Check out *Rocky Peak* to see the phenomenon in action.

Look at the photo and watch the video of different rock formations. What questions do you have about these rocks? Write your observations below.

Sample answer: How were these rocks formed? What can these rocks tell scientists? What clues might these rocks have that help scientists understand how landforms change? What patterns can be found in rock formations?

Did You Know?

Many of the rock formations in parts of the United States began forming approximately 100 million years ago.



INQUIRY ACTIVITY

Simulation

Fossil Dig

Have you ever stacked newspapers in a pile by placing the latest one on top? After a week, where would you find the oldest news in the stack? Just like your stack of newspapers, rock layers are stacked with the oldest layer found deep in the ground. Suppose you found a fossil. What might that fossil tell you about that layer of rock?

GO ONLINE

Use the simulation *Fossil Dig* to investigate layers of rocks and interpret the fossil evidence found at the dig site.

Make a Prediction What happens to the age of fossils as you dig deeper into rock layers?

Sample answer: I think that the deeper I dig, the older the fossils will be.

Carry Out an Investigation

1. Starting with Area 1, use the shovel tool to dig up each layer of rock. Click on each fossil found and tell where it lived and if it is older than the fossil found in the layer before.
2. Record your observations in the table. Use a separate piece of paper if needed.
3. Dig up Area 2, and repeat step 1.
4. Dig up Area 3, and repeat step 1.
5. Dig up Area 4, and repeat step 1.

Communicate Information

Area	Observations
Area 1	
Area 2	
Area 3	
Area 4	

6. What can you tell about the fossils found near each other in the same layer of rock?

Sample answer: Fossils that are found near each other in the same layer of rock have the same age and shared the same environment.

Construct an explanation by using the **pattern** in the fossil dig as evidence to support a claim about the environment over time.

Sample answer: The pattern shows that the deeper layers contain older fossils and that the environment changed over time. For example, a mammoth fossil over a shell fossil showed change from water to land.

Talk About It

Did your observations match your prediction?
Explain your findings to a partner.

VOCABULARY

Look for these words as you read:

fossil

sediment

sedimentary rock

What Fossils Tell Us

Sedimentary rock forms from sediments that are pressed together in layers. **Sediments** are tiny bits of soil or rock that have been broken down and deposited. Wind and water deposit most of the sediments. Over time, layers of sediment are formed with new sediments, which are deposited on top of older layers. Sedimentary rocks are formed by the weight of the top layers, or of water covering the sediment, pressing the sediment together. It can take millions of years for sediment to become rock.

Fossils, remains or imprints of living things from the past, are preserved in sedimentary rocks. Fossils give scientists information about environments of the past. Ammonites once lived in Earth's oceans. Ammonite fossils are found in rock that is now on dry land. This indicates that the land was once covered by water.

Ammonites lived in water. These fossil ammonites were found on land.

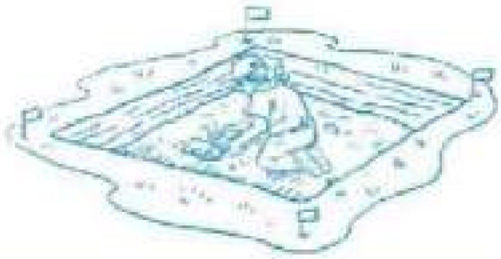
Scientists can also determine the relative age of fossils based on the layer of rock in which they are found. Some fossils also provide clues to a rock layer's relative age. How deep an organism is buried also gives clues as to when the organism lived. Fossils found in layers closest to the surface are usually younger than fossils that are found in deeper layers of rock.

GO ONLINE Watch the video *Fossils* to learn more about how they form.

Talk About It

What are the differences and similarities between sediment and sedimentary rock? Discuss with a partner.

1. How can scientists use evidence from fossils to determine changes in landscape over time? Give an example.



Sample answer: Fossils of ocean animals, like shells, found in rock layers under a forest area, would show that the area was once covered with water.

2. **WRITING Connection** Revisit the Inquiry Activity, *Fossil Dig*. Choose one of the areas in which you dug up fossils and write a time sequence story of what was happening at that site in the geologic past. Include at least three characters and dialogue in your story.

Students' stories should include events such as droughts, floods, or natural disasters causing the changes in the different layers.

GO ONLINE Watch *Fossil Dig* and learn how paleontologists find and recover fossils.

CLOSE READING

Inspect

Read the passage *Earth's Forces*. Underline the text that tells the forces that can change Earth.

Find Evidence

Reread the text. Are all Earth's forces the same? Highlight text that helps you understand.

Notes

Earth's Forces

Earth forces can affect the formation and patterns found in rock layers. Some of these forces include volcano eruptions, earthquakes, and the flow of rivers.

When a volcano erupts, it releases rocks, gases, and hot liquid rock called lava. Lava flows onto the surface, it cools, and hardens into new rock. A new layer of rock forms on top of the old layer each time a volcano erupts, like a stack of pancakes. This happens on continents and under oceans. An island can slowly form when enough underwater rock builds up to reach above the ocean surface. The Island of Hawaii formed this way.

Like volcanoes, earthquakes can change Earth's surface. During an earthquake, the sudden slip of two plates can cause cracks or can cause huge rocks to slide up over another layer. These changes can sometimes look like s-shaped folds in the rock layer.

Slow movements of Earth's plates can be very powerful too. When plates push together, they push up land. Over millions of years, these forces can form mountains. The Rocky Mountains, in Colorado, formed this way.

Water can interrupt rock layers by slowly removing rock particles. It slowly carves a gap in the layers, like when you cut and remove a piece of cake. Eventually a canyon forms. It took millions of years for the Colorado River to form the Grand Canyon.

Use evidence from each photo to support an explanation about how landscapes change over time.

Sample answer: A river would interrupt the rock layers, while an earthquake would most likely bend or shift the layers.

REVISIT PAGE KEELEY SCIENCE PROBES Revisit the Page Keeley Science Probe on page 27.

Make Connections

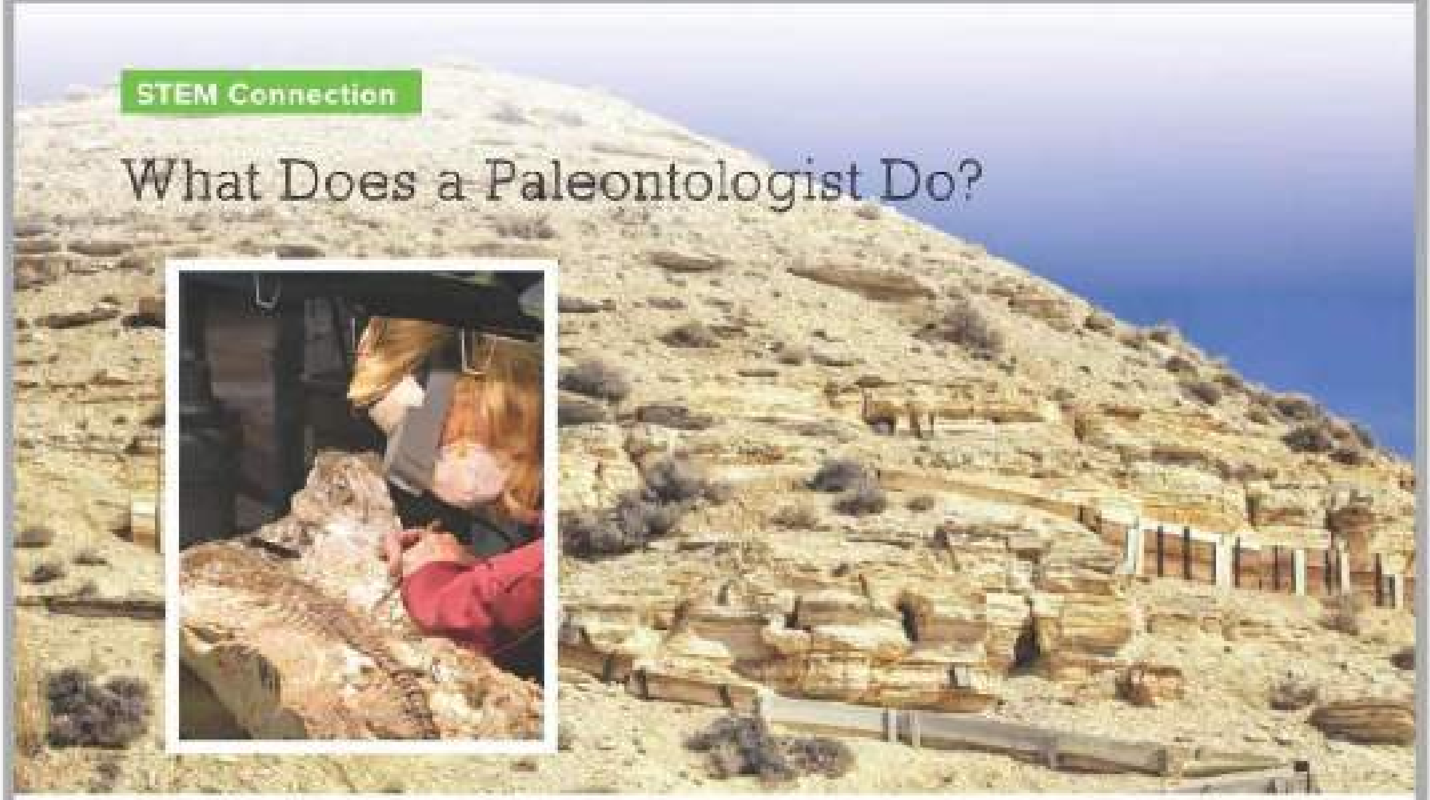
Talk About It

Explain a cause and effect relationship from the text. Discuss with a partner.

Notes

STEM Connection

What Does a Paleontologist Do?



Do you wonder what Earth was like when dinosaurs roamed the planet? Some scientists do too. **Paleontologists** are scientists who study living things, or organisms, that lived long ago. Paleontologists take detailed notes when researching in the field. Most of their work is focused on observing and collecting data from fossilized remains of ancient organisms. These organisms could be plants, animals, or microbes. They could range in size from a microscopic single cell to the fossilized remains of a dinosaur.

Talk About It

How do paleontologists help us learn about Earth's surface? Discuss with a partner.

It's Your Turn

Think like a paleontologist. Complete the activity on the next page to explore the relationship between fossils in rock layers and changes in landscape over time.

INQUIRY ACTIVITY

Hands On

Fossil Model

Suppose you had a stack of newspaper on a table. What would happen to the stack if you shook the table? You will create a model of fossils and rock layers to explore how scientists learn about the effect of Earth forces on rock layers.

Materials

multicolored modeling clay

classroom objects

Make a Prediction How would your fossil model change if it experienced an earthquake?

Sample answer: I predict that an earthquake would disturb or shift the rock layers in my model.

Carry Out an Investigation

1. Flatten each color of modeling clay until it is about 1/2 inch thick.
2. Place one or two small objects on top of each layer of modeling clay.
3. Place the layers of modeling clay with the objects on them on top of one another to create a stack of modeling clay of different colors. Press the layers down.
4. Exchange models with a partner. Tell your partner which side of your model is the top layer.
5. Take note of which color is on the bottom.

INQUIRY ACTIVITY

6. **Record Data** Draw and label the model before and after simulating an earthquake. Simulate an earthquake by applying a force on your model.

Before earthquake:	After earthquake:

Students' drawing should show that the layers shifted or bent after the earthquake simulation. Labels should identify the oldest layer, youngest layer, and the color of each layer.

7. Carefully pull the layers apart and remove the objects. Record which objects you found in which layer in the space below.

Sample answer: I found the eraser in the bottom layer, the paper clip in the middle layer, and a crayon in the top layer.

Communicate Information

8. What patterns do you notice in the model before and after the earthquake?

Sample answer: Before the earthquake, the layers were aligned with the oldest fossils on the bottom. After the earthquake, some of the layers bent or shifted upwards.

9. What causes older fossils to be found on the bottom layer of a fossil dig?

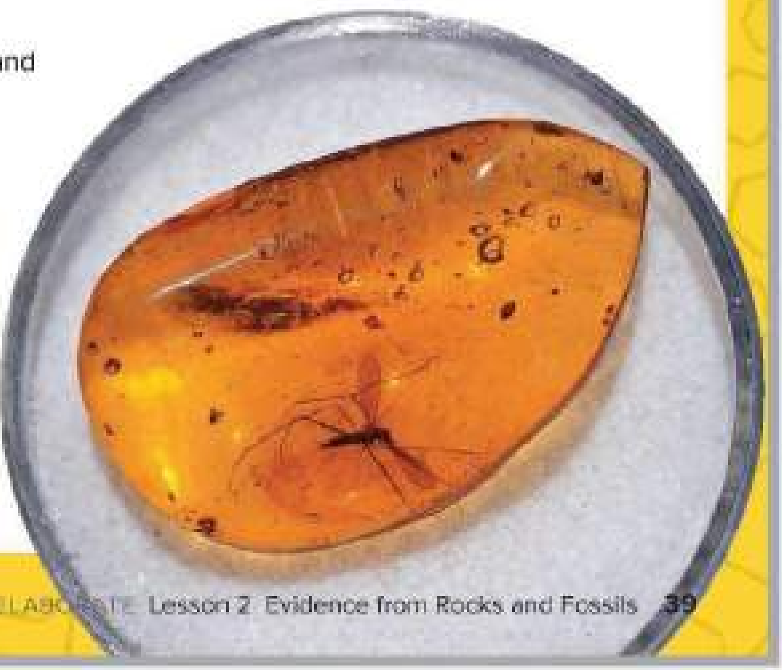
Sample answer: Over time, wind and water move small particles of soil known as sediment. This sediment covers the remains of living things and continually forms a new layer on top of an older layer.

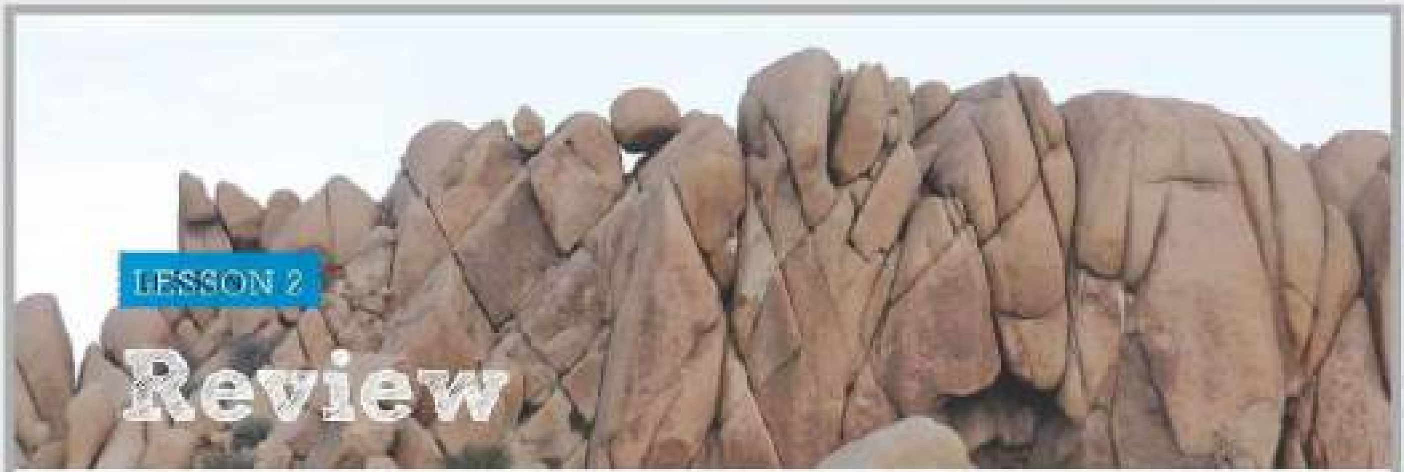
10. How could the flow of a river affect your model? What would happen if the river dried up?

Sample answer: A river would cut through the rock layers over time. If the river was to stop flowing, then the gap would be filled with newer sediment. This would cause an irregular pattern in the rock layers.

Talk About It

Share your model with a classmate and discuss ideas for improving your model to show the effect of Earth forces on rock layers.





LESSON 2

Review

EXPLAIN THE PHENOMENON

What information can we get from rocks?

Summarize It

Explain how we can learn about the past from rocks and fossils.

Sample answer: Fossils can reveal changes in an environment over time. For example, the rock layers beneath a forest can contain fossils of animals that lived in a watery environment. Also, the age of the rock layers and fossils increase the deeper we dig into the ground.

REVISIT PAGE KEELEY SCIENCE PROBES

Revisit the Page Keeley Science Probe on page 27. Has your thinking changed? If so, explain how it has changed.

Three-Dimensional Thinking

1. ______________ form from sediments that are cemented or pressed together.

   A. Sediments

   B. Fossils

   C. Sands

   D. Sedimentary rocks

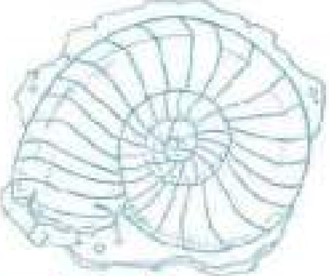
2. Use an analogy to explain how Earth forces affect the patterns found in rock layers.

   Sample answer: The flow of a river through a rock layer is like cutting a piece of a layer cake. Neither side of the layer cake is disturbed, but a gap is created.

3. What evidence can be used to explain the patterns found in rock layers?

   Sample answer: The age of fossils increases, the deeper they are found in the ground. Fossils can also reveal that a watery environment changed to dry land over time.

Extend It



You are a paleontologist. Research the area where you were born. Find out what types of living things lived in your place of birth thousands of years ago.

Write a speech, draw a poster, create a flyer, or use media to communicate your results to your class as a paleontologist.

Sample answer: As a paleontologist, I look for fossils to explain my environment. Each fossil I find gives me more information. My investigation reveals that my area was once under water. The sedimentary rocks in my dig site contained shells, and other remains from animals that could swim. It is exciting to know how much my area has changed over time.

KEEP PLANNING

STEM Module Project
Engineering Challenge

Now that you have learned about the evidence found in rocks and fossils in rock layers, go to your Module Project to explain how this evidence will affect your plan for your erosion solution design.

PAGE KEELEY SCIENCE PROBES

LESSON 3 LAUNCH

Changing Landforms

Three friends were talking about processes that change landforms. They each agreed that wind, water, and ice could wear away and change landforms. They disagreed on how long it takes for these processes to change landforms. This is what they said:

Bianca: *I think it takes a long time for these processes to change landforms.*

Rose: *I think it takes a short time for these processes to change landforms.*

Wyatt: *I think these processes sometimes change landforms quickly, but they can also take a long time.*

Whom do you agree with most? Wyatt

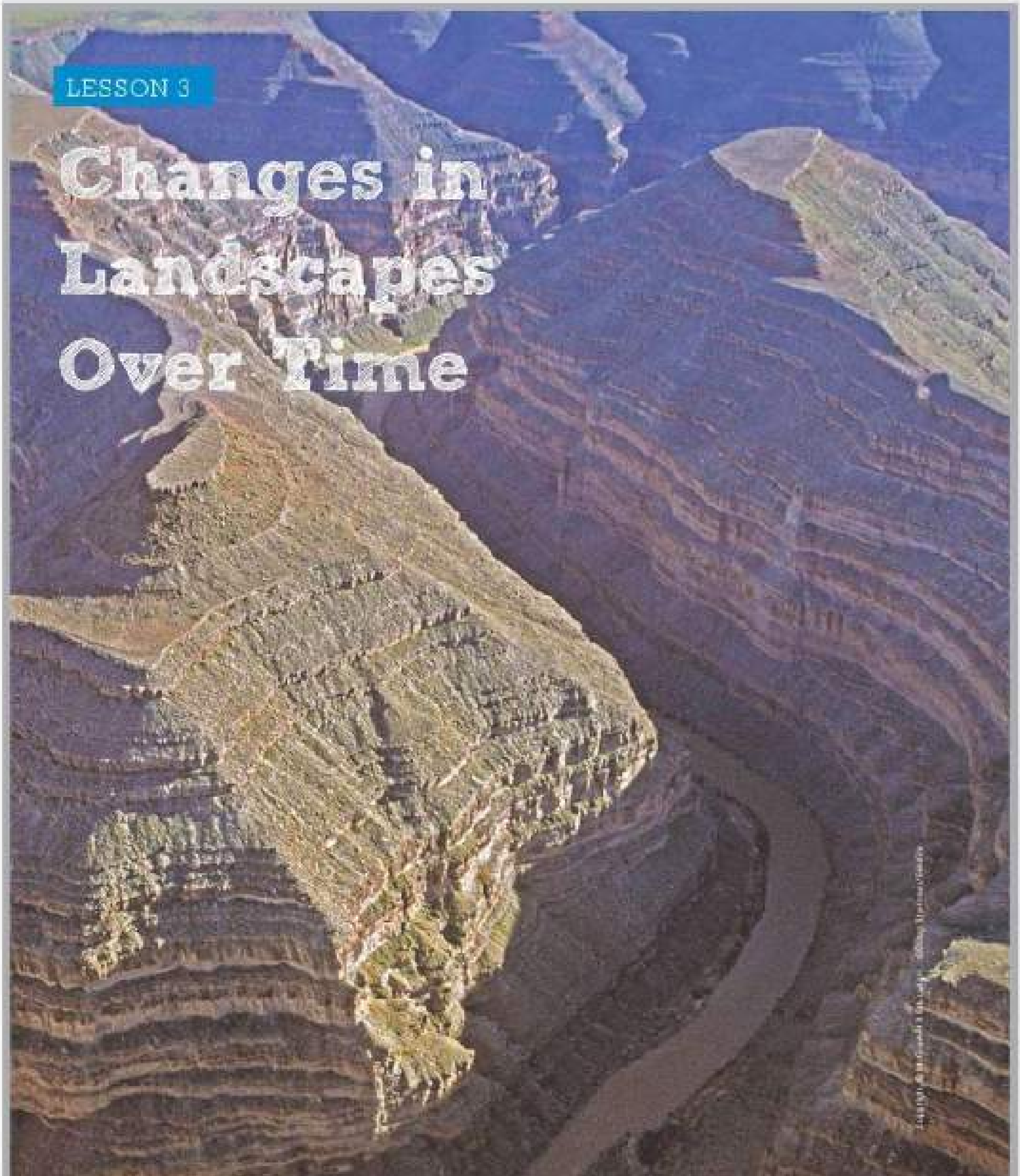
Explain why you agree.

Sample answer: The processes that change landforms can occur over long periods of time, such as the wearing away of mountains, or happen very quickly, such as a beach being washed away after a storm.

You will revisit the Page Keeley Probe later in the lesson.

LESSON 3

Changes in Landscapes Over Time



ENCOUNTER
THE PHENOMENON

How can moving water change the shape of land over time?

GO ONLINE

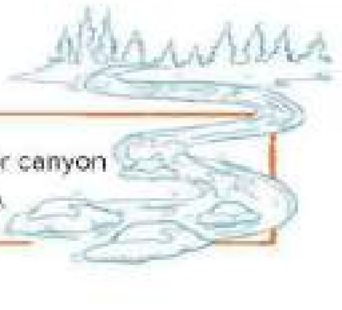
Check out *San Juan River* to see the phenomenon in action.

Look at the photo and watch the video of the river. What questions do you have about the phenomenon? What do you observe? Record or illustrate your thoughts below.

Sample answer: Has the land always looked the same? Is something causing the wearing of the rock? Do natural forces or human activity shape the land? Does human activity affect how fast land changes over time? How does the wearing of the land affect people?

Did You Know?

The San Juan River flows through a gorge or canyon that measures 300 meters (1,000 feet) deep.



INQUIRY ACTIVITY

Hands On

Shake, Rattle, and Roll

Have you ever seen a "river rock?" They are usually used in landscaping. How would you describe the shape of river rocks? In this investigation, you will model what happens to rocks in fast-moving river water.

Make a Prediction What will happen to rocks if you shake them in a container with water?

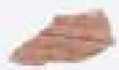
Sample answer: I think that the rocks will bump into each other and start to break as I shake the containers.

Materials


safety goggles


graduated cylinder

3 plastic jars with lids and water


sandstone rocks


stopwatch


hand lens


masking tape


marker

Carry Out an Investigation

BE CAREFUL Wear safety goggles.

1. Label three jars *No Shake*, *2-Minute Shake*, and *5-Minute Shake*. Place the same amount of similar-sized rocks in each jar.
2. Using the graduated cylinder, fill each jar with 50 mL of water. Firmly attach a lid on each jar.
3. Let the *No Shake* jar sit. Do not shake it.
4. Shake the *2-Minute Shake* jar hard for two minutes while your partner times the shaking with the stopwatch. Then let the jar sit.
5. Switch roles and use the stopwatch while your partner shakes the *5-Minute Shake* jar for five minutes. Then let the jar sit.
6. Use a hand lens to observe the rocks in each jar. Record your observation in the data table.

	Observations
No Shake	A few tiny bits of rock came off as the water poured over them.
2-Minute Shake	The rocks banged against each other and broke off bits of rocks.
5-Minute Shake	The rocks banged against each other and broke off a lot of rock pieces.

7. What do you think would happen if you shook the jar for an hour?

Sample answer: Pieces would keep breaking off until only smaller pieces of rock were left.

8. Do the results support your prediction? Explain.

Sample answer: Yes. The rocks broke into smaller pieces only in the jars that had moving water.

What **causes** the rocks in this investigation to change? Use your **observations** to support your claim.

Sample answer: The water moves rocks around, and when they bang into each other, they break apart.

Talk About It

Compare your results with those of a classmate. How could you improve the design of this investigation?

VOCABULARY

Look for these words as you read:

deposition

erosion

vegetation

weathering

Weathering

Recall the changes that you observed in the Inquiry Activity, *Shake, Rattle, and Roll*. You modeled weathering when you shook the jars. **Weathering** is the slow process that breaks down materials into smaller pieces. This process explains how rocks can change size and shape without changing their chemical properties.

Physical Weathering

Water can seep into cracks in a rock during warm weather. When the water freezes during cold weather, the water expands and makes the crack bigger. This process can also cause potholes and cracks in a road or sidewalk.

Abrasion is the action of rocks and sediments grinding against each other and wearing away surfaces. Abrasion can happen in many ways, such as when rocks and pebbles roll along the bottom of a river. Abrasion also occurs when rocks fall and tumble against one another. The force of the rocks hitting each other knocks off pieces of the rock. Wind causes abrasion. Sand blown by wind against exposed rock wears away the surface of the rock.

Rocks crashing together in a rockslide causes abrasion, a type of physical weathering.

Many animals, like gophers, worms, and ants, can loosen and move soil and break apart rocks as they burrow in the ground. Plant roots can grow inside cracks in a rock and, over time, split the rock into pieces.

GO ONLINE Watch the video *Landscapes Change Over Time* to learn more about these processes.

The actions of living things, such as burrowing animals or growing plant roots, can cause weathering.

What type of force can cause abrasion?

Sample answer: The force of gravity can cause rocks to fall and cause abrasion.

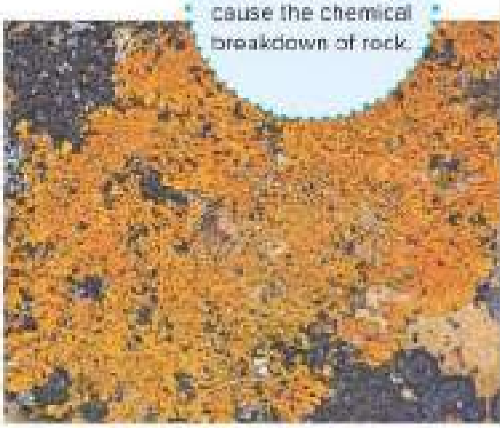
Chemical Weathering

Chemical weathering changes the minerals that make up rocks. Water, living things, and oxygen can cause chemical weathering.

Acids from natural sources, such as volcanoes, can make water more acidic. These acids can speed the breakdown and weathering of rocks.

Iron combines with oxygen in the presence of water to form rust. Rocks that contain iron can rust. Rust makes rock soft and crumbly.

Plant roots give off a weak acid as they grow. Lichens, plant-like organisms that grow on rocks, also produce weak acids. Lichens are important to soil formation in cold climates.



Lichens produce acids that help cause the chemical breakdown of rock.

Erosion and Deposition

Erosion is the movement of weathered material from one place to another. The process of eroded soil and bits of rock being dropped off in another place is **deposition**. Erosion and deposition are two processes that change the shape of land.

Erosion and Deposition by Gravity

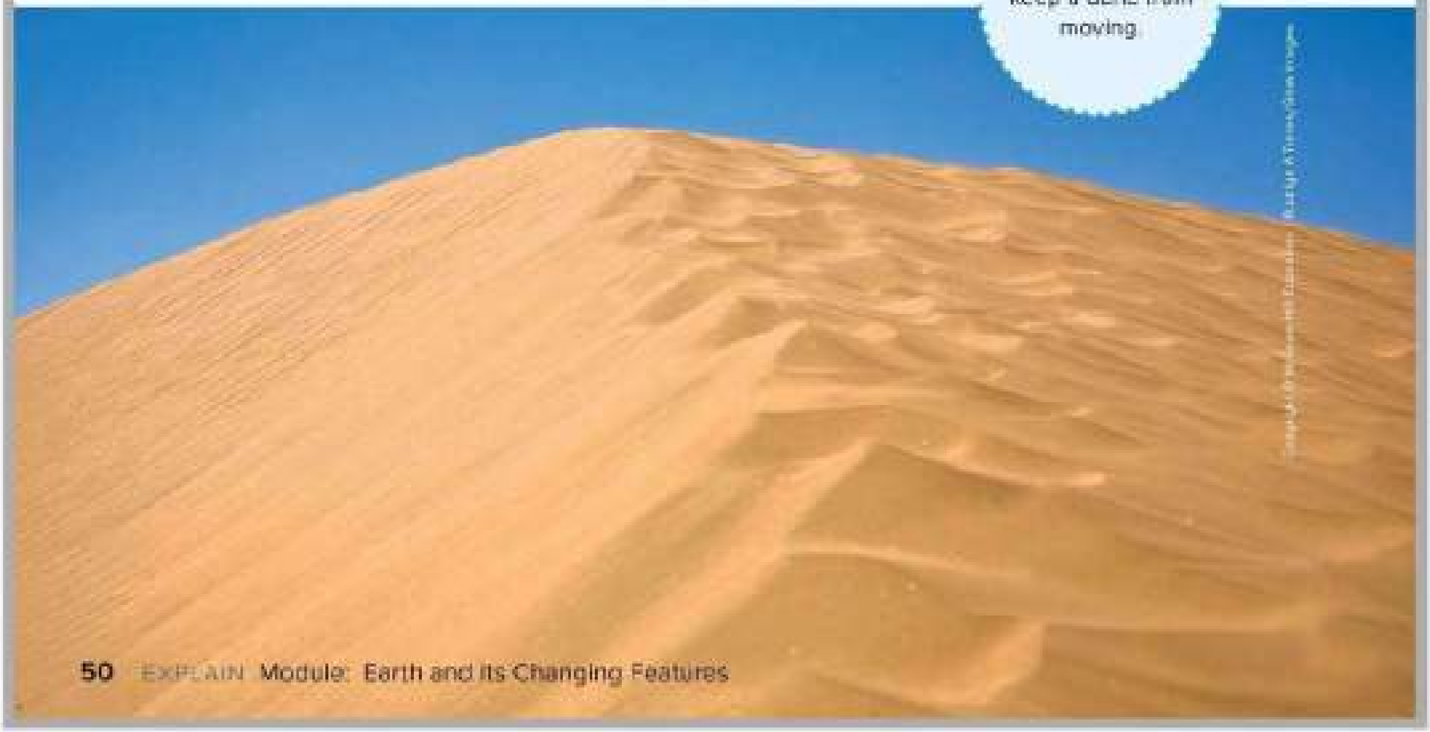
Gravity causes material to move. The sudden movement of large amounts of material down a slope can take the form of mudslides, landslides, and rockslides. Strategies such as building away from steep slopes, redirecting surface water away from landslide-prone areas, and planting ground cover to reduce water filtering into the ground can reduce hazardous events such as landslides.

Erosion and Deposition by Running Water

As water runs downhill, it can wash away soil and erode rock. The steeper the land, the faster the water moves. Fast-moving water has more energy. It can wash away larger amounts of heavier sediment. Rivers eventually flow into a larger body of water, such as a lake or an ocean. The sediment carried by the river is deposited on the bottom of the larger body of water. Over time, this sediment builds up into a landform called a delta.

Erosion and Deposition by Wind

Wind can move sand from one place to another. The stronger the wind blows, the larger the particles it can pick up. Deposition occurs when a clump of grass or rock traps the sediment. A sand dune is a deposit of wind-blown sand. Dunes move over time.



Plant roots can help keep a dune from moving.

Erosion and Deposition in Shorelines

GO ONLINE Watch the video *Weathering* to learn more about what shapes the land.

Waves release a lot of energy when they hit the beach. A large wave can break solid rock or throw rocks back against the shore. The rushing water in breaking waves can easily wash into cracks in the rocks, helping to break large boulders. The loose sand picked up by the waves polishes and wears down coastal rocks. Waves can also move sand and rocks and deposit them in other locations, forming beaches. A beach is any area of shoreline made of material deposited by waves. Some beach material is deposited by rivers.

A headland is an area that has water on three sides. Waves curve around a headland and erode the sides. Eventually, the waves change the headland into an arch.

1. Why does fast-moving water have a greater effect on land?

Sample answer: Fast-moving water has more energy so it can carry larger amounts of heavier sediment.

2. What are the cause and effect of the changes observed in the photo below?

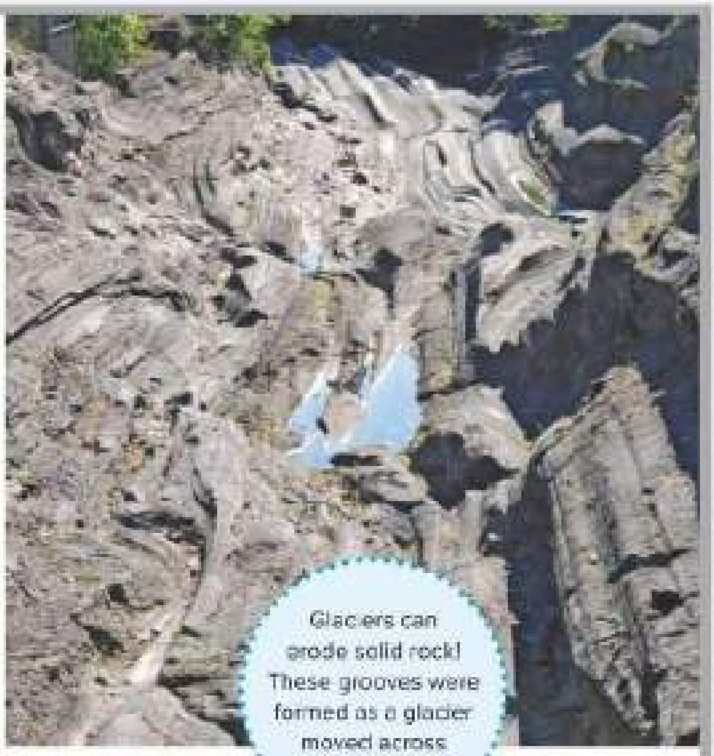
Sample answer: Waves cause the erosion of the rock and affect the formation of arches.

Erosion and Deposition by Glaciers

Glaciers form where snow collects quickly and melts slowly. As the snow builds higher, the weight of the ice increases, and the glacier starts to move. As it moves, it tears rock from the ground. Glacial till ends up mostly at the end, or terminus, of the glacier.

Erosion and Living Things

Factors such as heavy rainfalls, sparse vegetation, and steep inclines can cause land to erode at a faster rate. Heavy rainfalls can create new flooded habitats for migratory birds and other water dwellers. Fish lay eggs, and crayfish burrow in the fresh mud. Too much rain can also have negative effects on some wildlife. Heavy rains can destroy nests, burrows, and reduce food sources.



Glaciers can erode solid rock! These grooves were formed as a glacier moved across the land.

3. **ENVIRONMENTAL Connection**
How would the rate of erosion of a plain compare to the erosion of the side of a mountain if slope was the only factor to consider?

Sample answer: The mountain would erode faster since it has a higher slope.

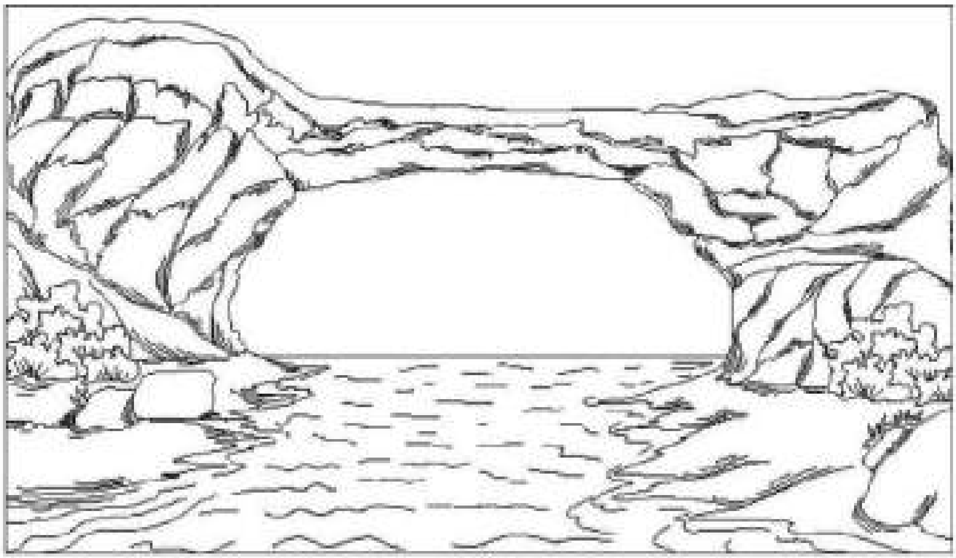
REVISIT PAGE KEELEY SCIENCE PROBES Revisit the Page Keeley Science Probe on page 43.

FOLDABLES

Cut out the Notebook Foldables tabs given to you by your teacher. Glue the anchor tab as shown below. Use what you have learned to describe how the terms relate to the image of the sea arch.

GO ONLINE Use the Personal Tutor *Weathering, Erosion, Deposition* to learn about how these processes change the shape of land.

Glue anchor tab here



INQUIRY ACTIVITY

Hands On

Effects of Vegetation

Think about where you have seen dirt and mud after a storm. Rain flows over the soil's surface when the land cannot absorb more water or if the water is moving too quickly to be absorbed. Does **vegetation,** plants that cover a particular area, have an effect on soil erosion? Recall what you have learned about plants and erosion.

Make a Prediction How does plant cover affect soil erosion caused by running water?

Sample answer: I think that the roots of plants help to keep soil in place so it does not erode as quickly.

Carry Out an Investigation

BE CAREFUL Use caution when handling the aluminum pan to avoid injury with the sharp edges.

1. Add soil to a small aluminum pan. The soil should measure 7 centimeters deep. Break up any clumps of soil that are present and pat the soil gently to make it level.
2. Place the wood block under one side of the pan so the pan is propped up 6 centimeters.
3. Position the small aluminum pan inside the larger pan, with the short side opening pointing down.
4. Fill your watering can with 500 mL of water. Tilt the can to simulate a steady, heavy rain over the soil. Let the water drain completely from the small pan.
5. Place a filter paper inside the funnel. Have your partner hold it in place.

Materials

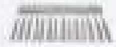

2 small aluminum pans


1 large aluminum pan


measuring cup


watering can with water


topsoil

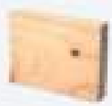

14 forks


filter paper

funnel


pan balance


ruler


wood block

GO ONLINE Explore *Factors of Weathering* to match environmental factors to the landforms they shaped.

6. Remove the small pan. Slowly filter the runoff water from the large pan over the sink until the water no longer drips from the funnel.

7. Weigh the amount of soil that was collected. Record this in the data table.

8. Now repeat steps 1–4 using the other small pan. This time you will "plant" forks to represent plants. Be sure to plant the 14 forks with the tines pointing down. The soil should reach the neck of the fork.

Communicate Information

Vegetation	Soil Mass (g)
No plants	18 grams
With plants	6 grams

9. Compare and contrast your investigation to a real-world situation.

Sample answer: In the real world, we do get heavy downpours that wash away soil. Places that have exposed dirt with little vegetation can have a lot of erosion. But you don't usually have erosion in places covered with plants, like a yard.

10. Describe the type of erosion to which the soil was exposed in this investigation.

Sample answer: The soil was exposed to weathering and erosion caused by water.

Talk About It

How could you improve this investigation? Tell a partner.

STEM Connection

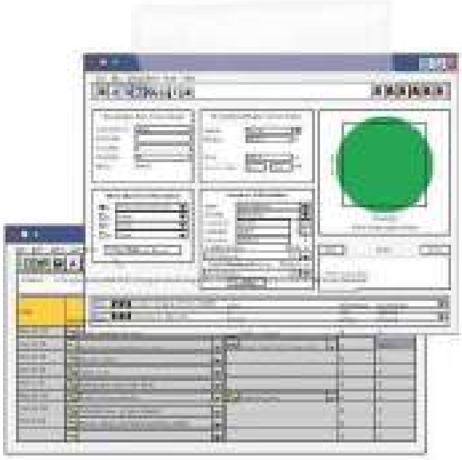
What Does a Soil Scientist Do?

John Tatarko is a **soil scientist** at the Wind Erosion Research Unit (WERU) and works on the Wind Erosion Prediction System (WEPS) simulator. He hopes WEPS will help farmers develop better ways to prevent erosion.

When asked "Can a Dust Bowl happen again?" he replied, "If we had weather conditions of the 1930s today for only a few years, wind erosion would not be as severe because of improved farming practices. The extent of drought and winds are up to Mother Nature."

Planning for the rest of the twenty-first century and beyond involves continuing research, practicing good land management, and being prepared.

Stripcropping, cover crops, windbreaks, and terraces are some land-management strategies that help reduce soil erosion.



The Wind Erosion Prediction System is a computer simulation program designed to predict soil loss by wind.

It's Your Turn

Think like a soil scientist. You will research and prepare a plan that includes three land-management strategies. Describe how each contributes to the conservation of Earth's natural resources. List your sources on a separate piece of paper.

GO ONLINE Use the simulation *Effects of Erosion on Landforms* to practice changing factors that affect landscapes.

Sample answer: Contour farming, windbreaks, and cover crops are three strategies that can reduce soil erosion. Contour farming controls runoff. Windbreaks protect soil from wind erosion. Cover crops protect the land from wind and water erosion.

Talk About It

How can technology help reduce soil erosion? Discuss with a partner.

Strip farming, windbreaks, breakwaters, vegetation, and terracing are some strategies that can help conserve soil.

LESSON 3

Review

EXPLAIN THE PHENOMENON

How can moving water change the shape of land over time?

Summarize It

Explain what causes the shape of land to change over time.

Sample answer: Land is constantly changing due to weathering. Some factors, such as the slope of the land, can increase how fast land changes. The steeper the land, the faster water moves. The faster water moves, the more energy it has to carry away a greater amount of material. The material that is carried away can then form other landforms, such as a delta at the end of the river.

REVISIT PAGE KEELEY SCIENCE PROBES

Revisit the Page Keeley Science Probe on page 43. Has your thinking changed? If so, explain how it has changed.

Three-Dimensional Thinking

1. Changes in the landscape can be caused by ____________.

    A. physical weathering

    B. chemical weathering

    C. living things

    D. All of the above

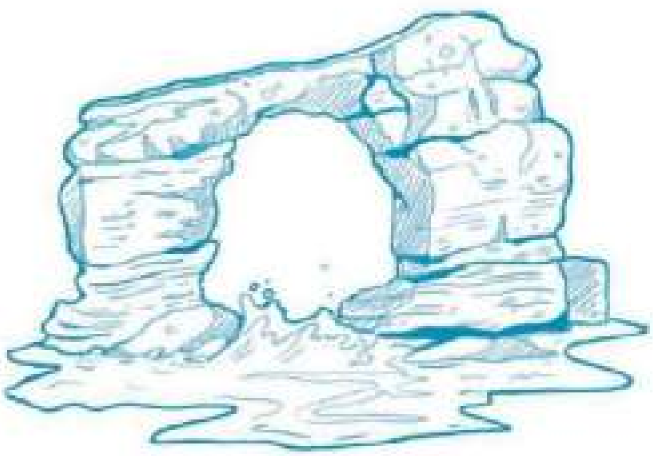
2. Weathering is the process that breaks down material.

3. Explain how heavy rainfall can affect the land and living things in an area.

Sample answer: Heavy rains can erode land at a faster rate. It can also provide new flooded areas for migratory birds and a place for water dwellers to lay their eggs. Too much rain can have negative effects on some wildlife. For example, it can destroy animals' homes and food sources.

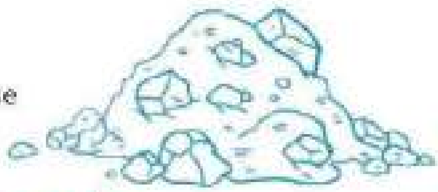
4. What can affect how fast land erodes?

Sample answer: The slope of the land, natural disasters, and the amount of rainfall can affect how fast land erodes.



Extend It

You are a soil scientist. Recall what you learned about land-management strategies. How might you communicate the best strategies that farmers could use to reduce erosion on their land? Write a speech, create a poster, or use media.



Students should explain how each land-management strategy contributes to the reduction of erosion on farmlands. They should address the benefits, disadvantages, and constraints for each strategy.

OPEN INQUIRY

What questions do you still have about how landscapes change over time?

Sample answer: What other strategies can home owners use to reduce the erosion of their land?

Plan and carry out an investigation or research to find the answer to your question.

KEEP PLANNING

STEM Module Project
Engineering Challenge

Now that you have learned about what contributes to the changes in landscape, go to your Module Project to consider this information as you design your soil erosion project.

STEM Module Project
Engineering Challenge

Don't Get Carried Away

You have been hired as a geologist. Using what you have learned throughout this module, you will work in a small group to design two solutions for soil erosion. You will build and compare the results of two models and select the design that best minimizes the effects of soil erosion. Include an explanation about how your design would affect neighboring property, reduce erosion damage on the land, and protect the environment. On a map, identify hazardous areas where you would not recommend building structures. Before you begin, discuss as a class the criteria and constraints of your project.

Planning after Lesson 1

Apply what you have learned about mapping Earth's features to your project planning.

How can we use maps to describe the shape of land?

Sample answer: Relief maps show the elevations on land. Physical maps can show the location of Earth's land and water. The contour lines on a topographic map can help us describe the slope of the land.

MAYA
Geologist

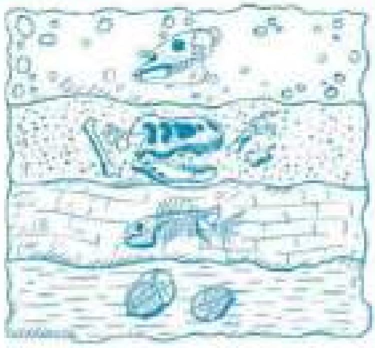
STEM Module Project
Engineering Challenge

Planning after Lesson 2

Apply what you have learned about evidence from rocks and fossils to your project planning.

How can we use our understanding of Earth forces to explain the changes in a landscape over time?

Sample answer: Earth forces such as earthquakes can shift or bend layers of rock. An earthquake can change a landscape by triggering landslides, rockslides, or mudslides.



Planning after Lesson 3

Apply what you have learned about changes in landscape to your project planning.

What factors should be considered when trying to design a solution to erosion?

Sample answer: Factors such as the slope of the land, the amount of rain, and the amount of wind should be considered when designing a solution for erosion.

Research the Problem

Research the factors that help shape the land by reading the Investigator article, *Movers and Shapers*. Then, go online to teacher-approved websites, or find books on erosion solutions at your local library.

Students should use teacher-approved websites. They should find information on designs for wind fences, embankments, and other land management strategies to help them develop their own design.

Sketch Your Model

Draw and label your ideas in the space below. Select two models to build and test.

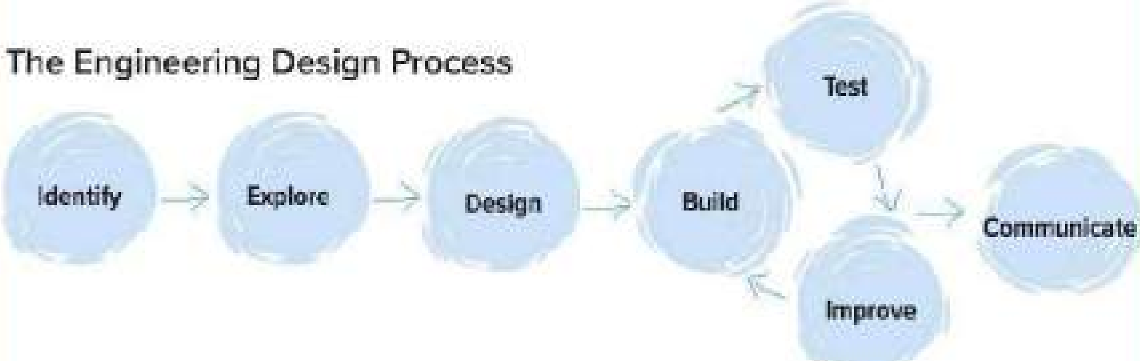
Students' drawing should show two different designs that help retain soil but still allow water to flow.

STEM Module Project
Engineering Challenge

Don't Get Carried Away

Look back at the planning you did after each lesson. Use that information to complete your soil erosion project. As part of the design criteria, your models should be able to hold back soil, and allow water through. The constraints are that your models should be easy to install and should not cause harm to neighboring properties or the environment.

The Engineering Design Process



Build Your Model

1. Identify a problem caused by erosion and come up with at least two solutions on how to prevent it. You may want to research soil-erosion solutions that engineers have designed.
2. Determine the criteria for your models, and list the materials you will use to build your models.
3. Refer to your project planning notes as you build your models.
4. Record the steps of your procedures to carry out fair tests of your models. Identify variables in each test.
5. Use the test results to compare your two models. Then select the design that best meets the criteria and constraints of the project.

Materials

non-vinyl tubing, sand, modeling clay, gravel, small plants, blocks, cotton balls, sponge, aluminum pan, watering can

Procedure:

Students should list the steps of their procedure here. Solutions might include: building a wind fence to reduce soil or beach/dune erosion; building an embankment to keep water from running off roads and eroding surrounding land; or planting a hill with fast-growing plants to hold soil in place.

Test Your Model

Build and test your models. Record your observations and results. Use a data table or separate piece of paper, if needed. Select the design that best meets the criteria, and present it to another group. Share your research, and provide feedback on each other's solutions.

MATH Connection Calculate the amount of soil that erodes for each model. Show your work on a separate piece of paper.

STEM Module Project
Engineering Challenge

Communicate Your Results

Share the plan for your models and your results with another group. Compare how well each of your models was able to meet the criteria of withstanding the process of erosion. Discuss how well your models met the criteria and constraints, and ways you can improve your models. Communicate your findings below.

Sample answer: I was able to slow down the flow of water by routing the water to a water canal in my model. However, it was challenging not to affect the surrounding areas. Another group's design used underground tubing to protect the surrounding properties and route the water to a nearby river, while still protecting the environment.

MODULE WRAP-UP

REVISIT THE PHENOMENON

Using what you learned in this module, explain how Earth's land features were formed.

Sample answer:
Land features such as sea arches were slowly weathered by the forces of water and wind. Moving water has energy that carries away material to other locations. Gravity can also cause rocks to crash into one another and knock off pieces of rock. Finally, wind can blow sand and wear away the rock's surface.

Revisit your project if you need to gather more evidence.

How have your ideas changed? Explain your answer.

Sample answer: Yes, land management strategies can help reduce soil erosion caused by wind, and water.

Earthquakes

Look at some of the damage caused by the 1989 Loma Prieta earthquake in San Francisco, CA!

ENCOUNTER THE PHENOMENON

Why do you think this building collapsed, but the others did not?

GO ONLINE
Check out *California Earthquakes* to see the phenomenon in action.

Talk About It

Look at the photo and watch the video of an earthquake causing a building to collapse. What questions do you have? How might an earthquake cause a building to collapse? Talk about it with a partner.

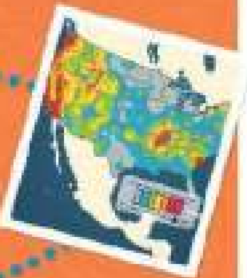
Did You Know?

About 50 earthquakes happen somewhere in the world each day. Each year, there are about 20,000 earthquakes worldwide.

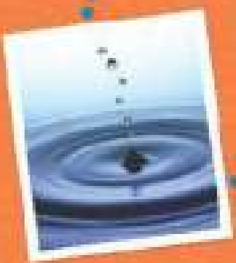
STEM Module Project Launch
Engineering Challenge

Design an Earthquake-Resistant Building

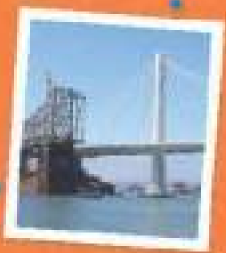
Lesson 1
Map Earthquakes



Lesson 2
Model Earthquake Movement

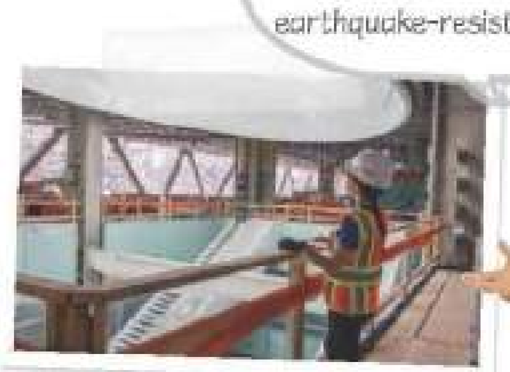


Lesson 3
Reduce Earthquake Damage



How do some buildings stay standing during an earthquake while others do not? At the end of this module, you will work with a small group to develop two designs for a school. You will design, build, and test two models of a school building to determine their ability to resist the forces of an earthquake. You will compare the test results of your two models and select the model that best minimizes earthquake damage.

You will be a structural engineer and design two earthquake-resistant buildings.



Jane Horvath is a structural engineer. She uses her knowledge of materials, forces, and earth science to design safe structures. Structural engineers apply what they know to design structures that are safe.

FINN
Construction Manager

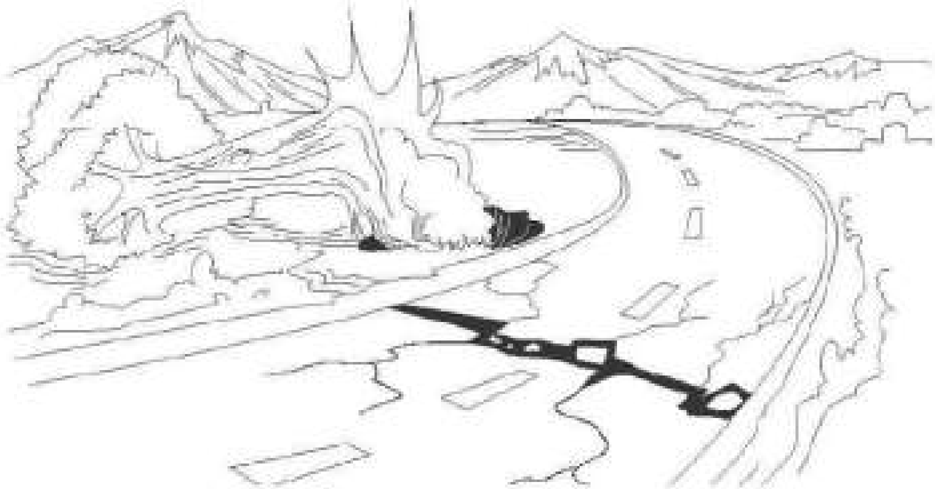
STEM Module Project

Plan and Complete the Engineering Challenge You will use what you learn to build and test your buildings!

PAGE KEELEY SCIENCE PROBES

LESSON 1 LAUNCH

Locations of Earthquakes



Two friends were talking about earthquakes. They wondered if earthquake locations followed a pattern.

Jerome: *I think earthquake locations follow a pattern. They usually occur near certain land and ocean features.*

Anjali: *I think there is no pattern to earthquake locations. They can happen anywhere in the world.*

Who do you think has the best idea? Jerome

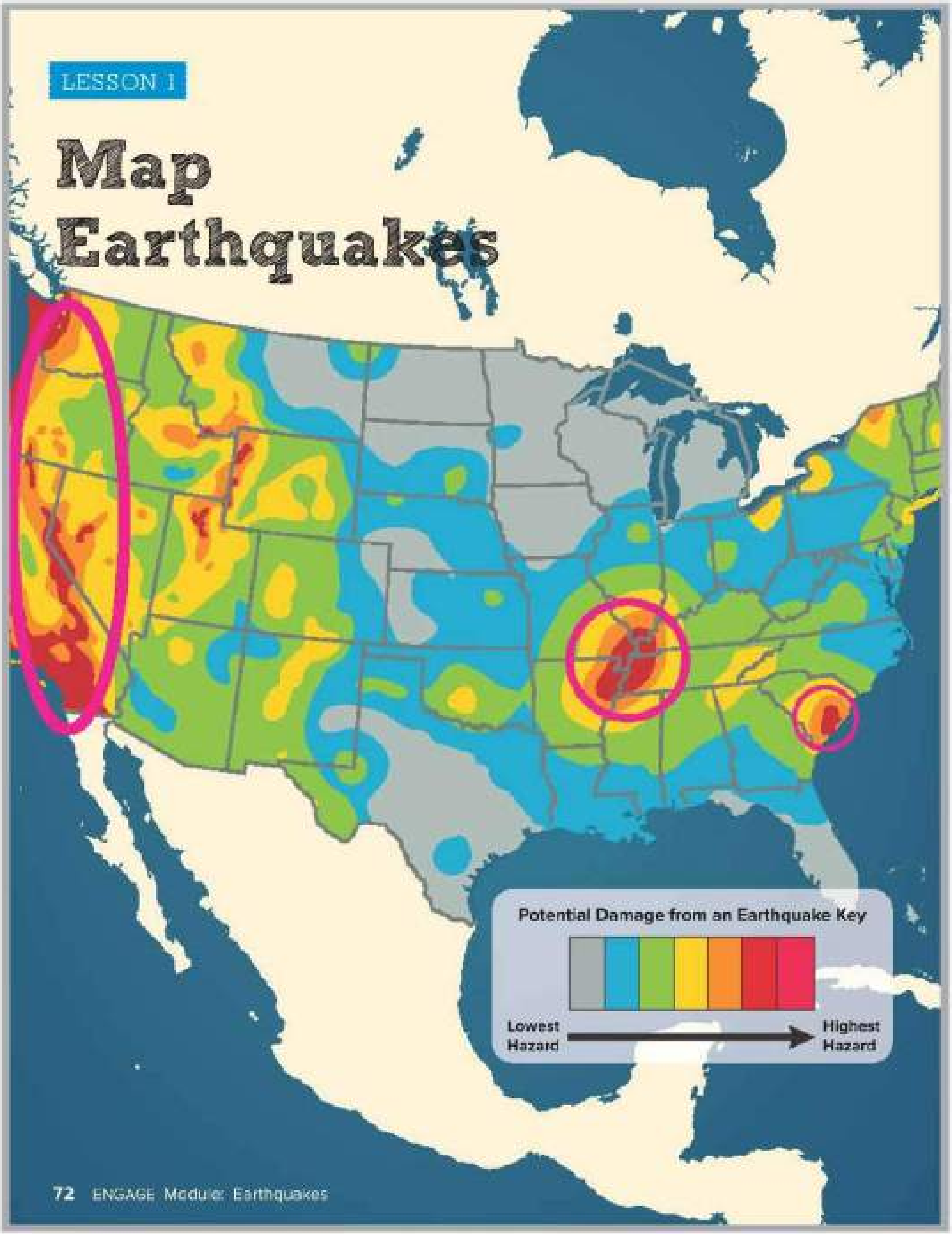
Explain your thinking.

Sample answer: Earthquakes occur along continental boundaries and certain landforms, such as mountain ranges and volcanoes.

You will revisit the Page Keeley Science Probe later in the lesson.

LESSON 1

Map Earthquakes



ENCOUNTER
THE PHENOMENON

Why are earthquakes more likely to occur in some places rather than others?

GO ONLINE

Check out *Earthquake Occurrences* to see the phenomenon in action.

Look at the map showing occurrences of earthquakes in the continental United States.

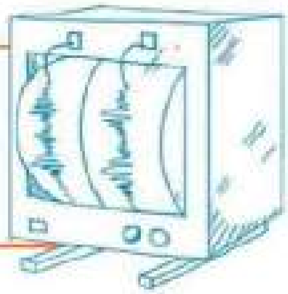
Talk About It

Circle the areas on the map that have the highest risk for earthquakes. Use the map's key to help you. What do you observe? Talk about your ideas with a partner. Record your thoughts below.

Sample answer: Do Earth's features affect the occurrence of earthquakes? Are there any areas on Earth that never experience an earthquake?

Did You Know?

Southern California experiences about 10,000 earthquakes a year! This is quite different from Ohio, where only about 200 earthquakes have been recorded since 1776.

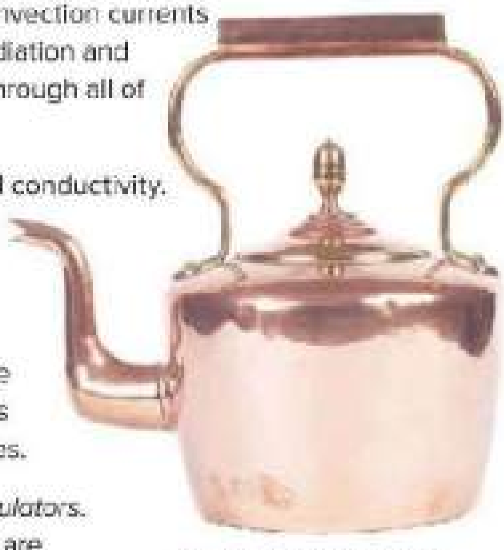


Thermal Conductivity

Thermal energy travels at different speeds. Thermal energy is carried by radiation through empty space at the speed of light. Convection currents travel slower. Conduction is usually slower than both radiation and convection. In conduction, thermal energy must travel through all of the particles of matter.

The ability of a material to transfer heat is called thermal conductivity. Materials that conduct heat easily are good thermal *conductors*. Most metals are thermal conductors. Thermal conductivity usually increases with density. Density is the amount of matter in an object. When particles in a material are closer together, heat can move more quickly through them. Solids are better conductors than liquids, and liquids are better conductors than gases.

Materials that conduct heat poorly are called thermal *insulators*. Air, for example, is a thermal insulator. Most winter coats are puffy because they contain pockets of air that prevent heat from moving away from your body.



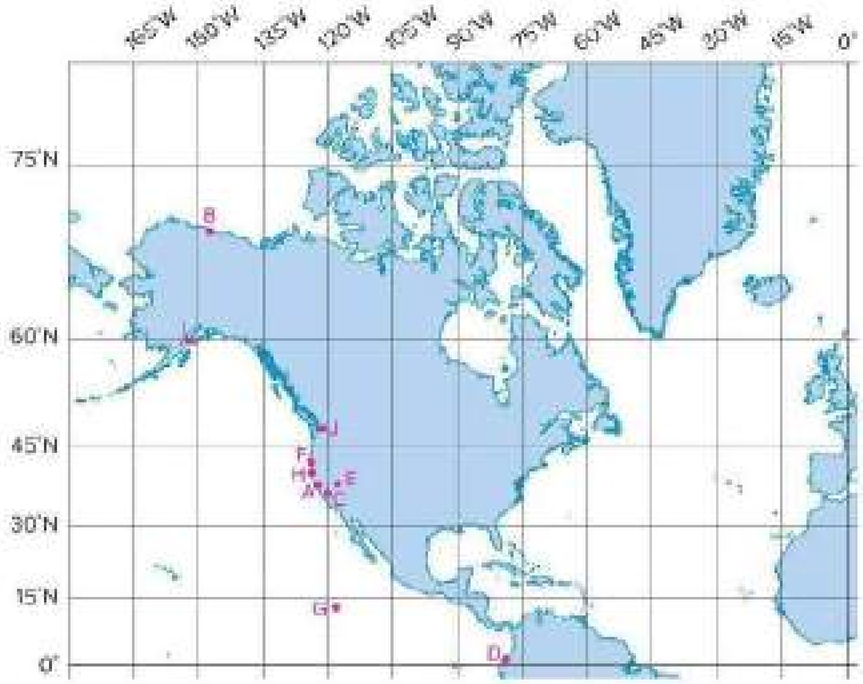
This copper pot is a good thermal conductor.

Thermal Conductivity

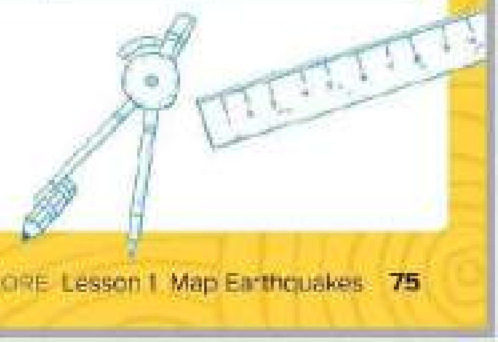
Material	How Many Times Better Than Air It Conducts Heat
Oak wood	6
Water	23
Brick	25
Glass	42
Stainless steel	534
Aluminum	8,300
Copper	15,300
Silver	16,300

Use evidence to explain which material from the table above is the best thermal conductor.

Silver is a solid, a metal, and is 16,300 times better than air in transferring heat, which makes it the best thermal conductor.



Earthquake Locations					
Earthquake	**Latitude**	**Longitude**	**Earthquake**	**Latitude**	**Longitude**
A	37° N	122° W	F	41° N	125° W
B	69° N	147° W	G	14° N	118° W
C	36° N	120° W	H	40° N	125° W
D	1° N	79° W	I	60° N	152° W
E	37° N	118° W	J	48° N	121° W



INQUIRY ACTIVITY

3. Look at the locations that you plotted on the map. Does your evidence support the prediction that you made about where earthquakes occur?

Sample answer: Yes, most earthquakes occurred along the boundaries of land and water.

4. How could you find out more about where earthquakes occur?

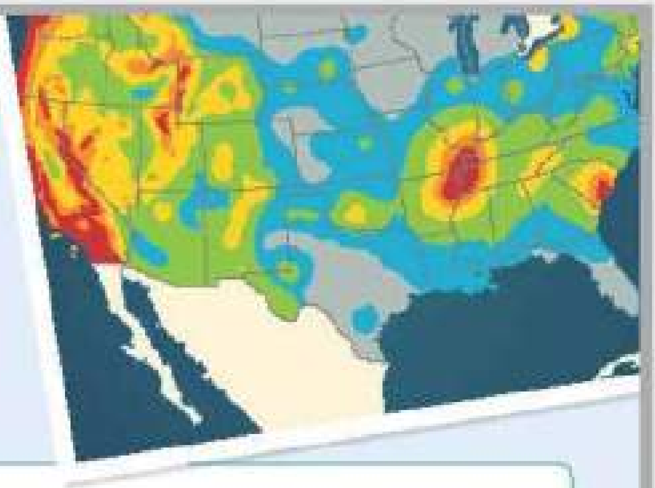
Sample answers: I could use books to learn more or go online to teacher-approved websites. I could talk to a scientist who studies earthquake activity in my area.

5. **MATH Connection** Think about how you could teach a younger student to do this activity. Explain how you plotted the points on the map using longitude and latitude.

Sample answer: I used the table to plot the points on the map. Lines of latitude run right to left and lines of longitude run up and down on the map.

MAKE YOUR CLAIM

Where do you think future earthquakes in the continental United States are most likely to occur?



Make your claim. Use your investigation.

CLAIM

Future earthquakes are most likely to occur ________________.

Sample answer: along plate boundaries.

Cite evidence from the activity.

EVIDENCE

The investigation showed that ________________.

Sample answer: all of the plotted points were located along the west coast of the North America continent.

Discuss your reasoning as a class. Tell about your discussion.

REASONING

The evidence supports the claim because ________________.

Sample answer: energy builds up as plates grind against each other at plate boundaries. Earthquakes occur when the built up energy is released and reaches Earth's surface.

You will revisit your claim to add more evidence later in this lesson.

Earthquakes

VOCABULARY

Look for these words as you read:

fault

GO ONLINE Watch the video *Earthquake Mapping* to learn more about patterns in earthquakes occurrences.

Earth's crust is made up of huge slabs of solid rock, called plates, that are always in motion. There are breaks or cracks where these plates come together. These cracks are called **faults**. In some places, Earth's plates can slide slowly past each other along a fault. In other places, plates can push together, move under or over each other, or even move apart from each other. This type of plate movement causes earthquakes to occur.

You have learned that earthquakes are movements in Earth's crust that are caused by a sudden shift of Earth's plates. The constant movement of Earth's plates puts stress on rock that is on both sides of a fault. As plates grind against each other, energy builds up in these rocks. When this energy is released, the crust shakes, vibrations reach Earth's surface, and an earthquake occurs.

The San Andreas Fault is an area where many earthquakes occur. This fault line sits between a continental and oceanic boundary.

Patterns of Earth's Features

Below is a topographic map of the world. This map shows different landforms, such as mountain ranges and deep ocean trenches, which usually form along the boundary of two oceanic plates or an oceanic and continental plate. The map also outlines the continental boundaries and boundaries between continents and oceans. Many faults are located along these boundaries. In the Inquiry Activity, *Plot Earthquakes*, most of the points you plotted on the map were along the plate boundary between North America and the Pacific Ocean. Think about the relationship between the earthquake locations you plotted and the locations of landforms and plate boundaries shown on the map below.

GO ONLINE Use the simulation *World Earthquakes and Volcanoes* to explore patterns in the location of earthquakes and volcanoes.

Talk About It

Discuss with a partner any patterns you observe in the locations of Earth's features and the locations of earthquakes.

GO ONLINE Explore *Patterns on Earth's Surface* to learn more about mountain ranges, earthquakes, and volcanoes.

CLOSE READING

Inspect

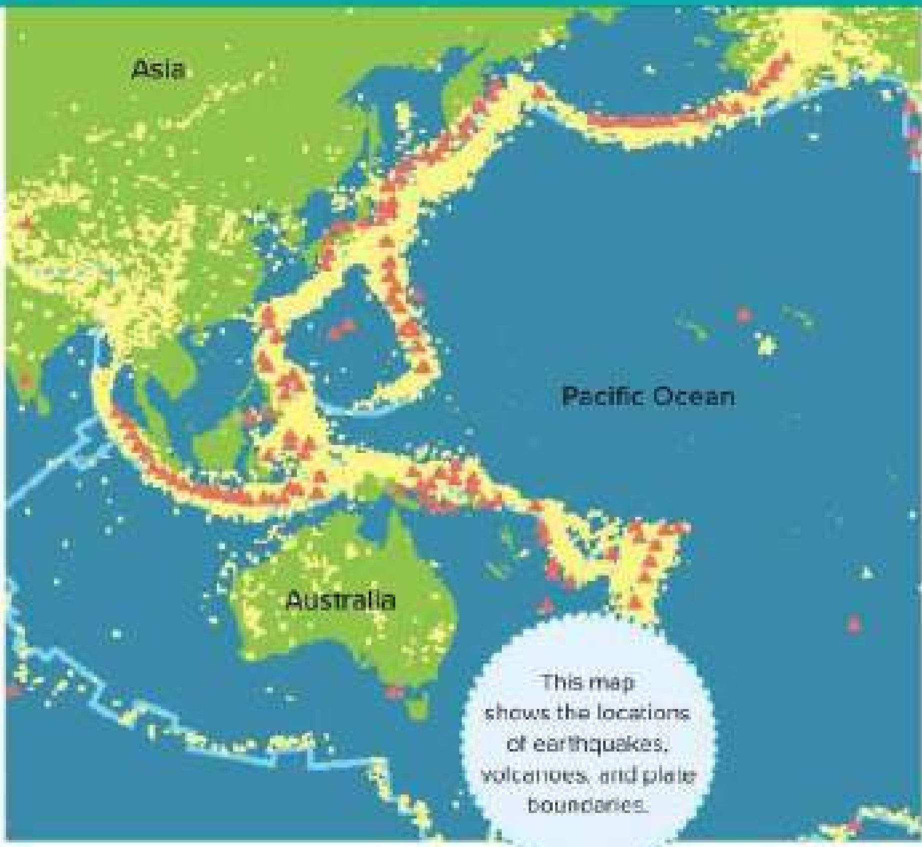
Read the passage *Where Earthquakes Occur.* Underline text evidence that tells where earthquakes occur.

Find Evidence

Reread How do you know there is a pattern to where earthquakes occur?

Highlight the text evidence that supports your answer.

Notes



This map shows the locations of earthquakes, volcanoes, and plate boundaries.

Where Earthquakes Occur

Looking at the map above, you can see that most earthquakes happen along the edges of ocean and continental plate boundaries. There is an area around the Pacific Ocean where a number of Earth's plates meet. This area is known as the "Ring of Fire" because many earthquakes and volcanic eruptions occur here. If you compare this map to the topographic map from earlier in the lesson, you can see that mountain ranges and deep ocean trenches are also found near or along continental and ocean plate boundaries. This pattern of earthquake locations helps seismologists, scientists who study earthquakes, to understand where earthquakes are likely to occur. However, it is difficult for seismologists to predict when an earthquake will occur.

Make Connections

Talk About It

How might an engineer work together with a seismologist to design a new tool for earthquake investigations?

Notes

The San Andreas Fault in California runs along the boundary between the North American and the Pacific Ocean plates, where a number of earthquakes occur. Other areas, like California, experience many earthquakes. In these areas, seismologists monitor changes in the ground with the use of instruments that measure bulges or changes in the angle of the ground.

Label the San Andreas Fault on the map. How can you **analyze and interpret data** to explain a **pattern** in its **location**?

Sample answer: Earthquakes occur along plate boundaries.

REVISIT PAGE KEELEY SCIENCE PROBES Revisit the Page Keeley Science Probe from earlier in the lesson.

STEM Connection

What Does a Cartographer Do?

Cartographers study landforms and create maps. They use several sources of data to create different types of maps. Cartographers usually gather data from the field. This means they will go to the place they are mapping rather than just use photos. Cartographers may see changes in the land as construction or natural hazards occur.

Long ago, cartographers would drew maps by hand. While some may still use this method, now they can use computers and satellite images to draw interactive maps.

It's Your Turn

Think like a cartographer. Complete the Inquiry Activity, *Earth's Features*. Explore the relationship between landforms and earthquakes.

Talk About It

How would a structural engineer benefit from the information a cartographer can provide?

INQUIRY ACTIVITY

Research

Earth's Features

Materials


scissors

You will investigate a pattern in the location of Earth's features and earthquakes.

Make a Prediction Is there a pattern between the location of landforms and where earthquakes occur? Explain.

Sample answer: Yes, I think there is a pattern. Mountain ranges and boundaries are located where earthquakes occur.

Carry Out an Investigation

1. Use the topographic world map provided by your teacher. Cut along the boundary lines. There should be 16 pieces total.

2. Compare your completed puzzle to the the world maps in the lesson. Look at where the plates come together in your puzzle. How does this relate to where earthquakes occur? What causes earthquakes?

Sample answer: Earthquakes happen along the boundaries of oceans and continents. Plate movement causes earthquakes to occur.

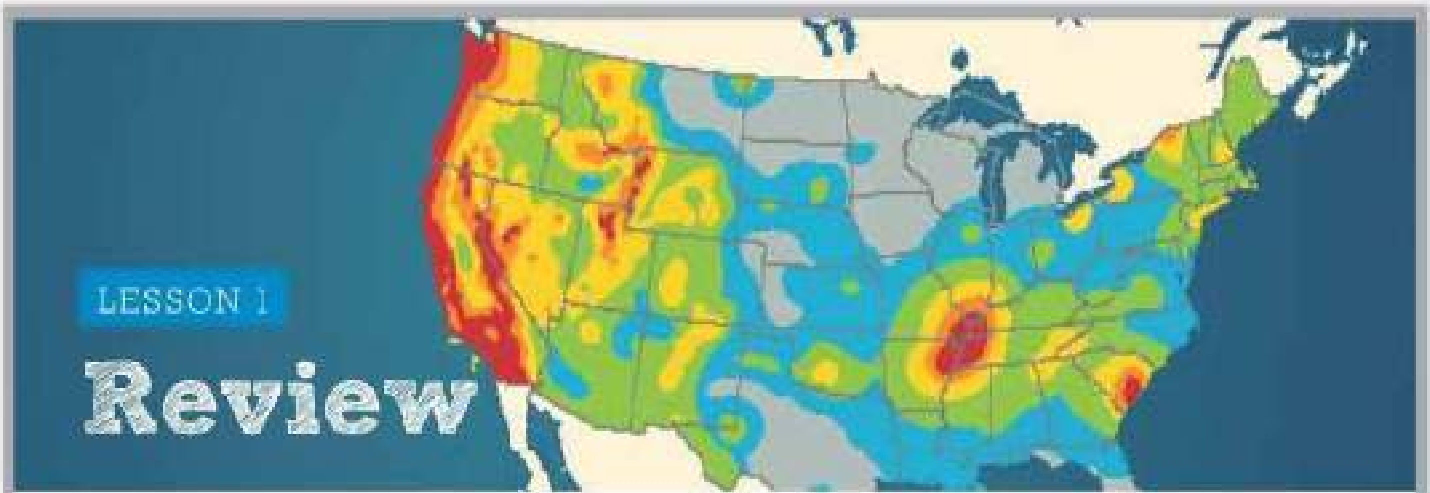
Communicate Information

3. ENVIRONMENTAL Connection How would a higher chance of earthquakes in an area affect life for the people who live there?

Sample answer: People in these areas might be concerned about how earthquakes can damage their homes.

COLLECT EVIDENCE

Add evidence to your claim from earlier in the lesson about where future earthquakes will occur.



LESSON 1

Review

EXPLAIN THE PHENOMENON

Why are earthquakes more likely to occur in some places rather than others?

Summarize It

Explain why earthquakes are more likely to occur in some places than others.

Sample answer: Earthquakes occur in a pattern along boundaries between continents and oceans. They also occur near landforms, such as mountains. California is an area that is located near a continental boundary and mountains.

REVISIT PAGE KEELEY SCIENCE PROBES

Return to the Page Keeley Science Probe. Has your thinking changed? If so, explain.

Three-Dimensional Thinking

1. The map below shows Earth's crust broken into 12 major plates. These plates are in constant motion, and Earth experiences earthquakes every day.

Think about patterns of earthquakes. Which number on the map shows where earthquakes are most likely to occur?

A. 1
B. 2
C. 3
D. 4

2. Looking at the map above, explain what you know about the pattern of where earthquakes occur.

Sample answer: Although earthquakes occur all over the world, there is a definite pattern. Most earthquakes occur in the same areas as volcanoes and along the boundaries of oceans and continents.

Extend It

Use evidence from the lesson to support your opinion about whether or not homes in your area should have earthquake-resistant structures.

Sample answer: I think that homes in my area should have earthquake-resistant structures so that we are more prepared. California has a large fault line where many earthquakes occur. Having a house that is earthquake-resistant would help people to be more safe when an earthquake occurs.

OPEN INQUIRY

What questions do you still have about earthquakes?

Sample answer: Have researchers designed new ways for making structures earthquake resistant?

Plan and carry out an investigation or research to find the answer to your question.

KEEP PLANNING

STEM Module Project

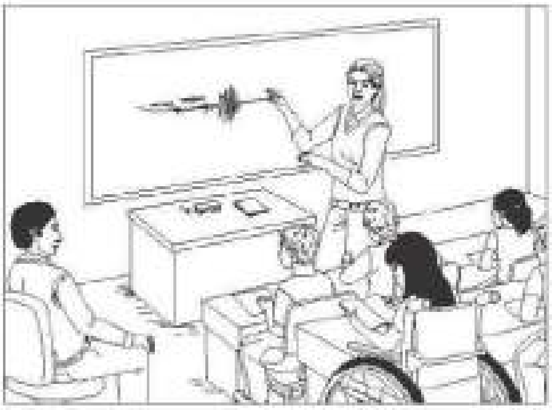
Engineering Challenge

You have learned where earthquakes occur. Go to your Module Project and explain how the information will affect your plan for your building.

PAGE KEELEY SCIENCE PROBES

LESSON 2 LAUNCH

Ground-Shaking Event



Mrs. Morales' students shared different ideas they had about how earthquakes moved. Mrs. Morales then invited a seismologist from the Southern California Earthquake Center to talk to the class about earthquakes. She talked about how earthquakes moved. After the students listened to the seismologist's talk, Mrs. Morales asked the students to revisit their ideas. Which idea do you think is now the best idea?

Tania: *Earthquakes have the same strength and shake at the same speed.*

Blanca: *Earthquakes have the same strength and shake at different speeds.*

Maeve: *Earthquakes have different strengths and shake at the same speed.*

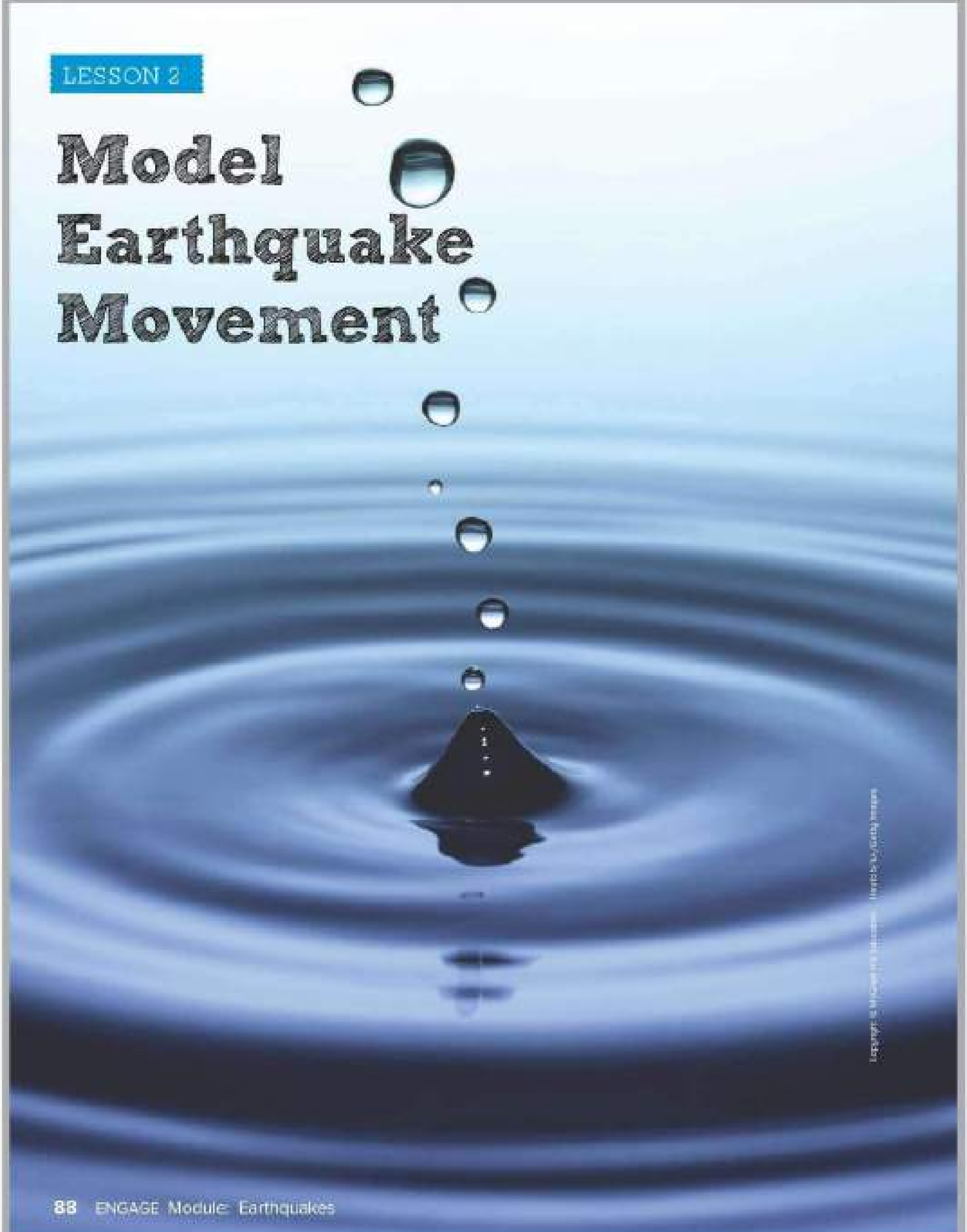
Romaytha: *Earthquakes have different strengths and shake at different speeds.*

Who do you think has the best idea? Romaytha

Explain your thinking.

Sample answer: Earthquakes have different strengths and move at different speeds. Some can shake the ground with great intensity and cause a great amount of damage to structures and even cause death.

You will revisit the Page Keeley Science Probe later in the lesson.



LESSON 2

Model Earthquake Movement

ENCOUNTER
THE PHENOMENON

How do water ripples model earthquake movement?

GO ONLINE

Check out *Water Drop* to see the phenomenon in action.

Talk About It

Look at the photo and watch the video of a water drop. What do you observe? Have you ever experienced this phenomenon before? Talk about your questions with a partner. Record your thoughts in the space below.

Sample answer: What makes the ripples? Why are some ripples bigger than others? How fast do the ripples move?

Did You Know?

Earthquakes travel in waves across Earth and through the layers of Earth.

INQUIRY ACTIVITY

Hands On

Make Waves

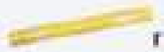
Think back to the photo you saw at the beginning of the lesson. The drop of water produced small, gentle waves. A larger disturbance, like a speeding boat, would produce larger waves. What happens when waves reach objects floating in the water? In this activity, you will observe the effects that different types and sizes of waves have on objects.

Make a Prediction Will waves move the objects to a different position? Explain your answer.

Sample answer: No. The objects will move up and down and back and forth, but they will not change their overall position.

Materials


aluminum pan with water


ruler


cork


spring toy


modeling clay


masking tape

Carry Out an Investigation

1. Fill the pan with water to a depth of 2.5 cm. Place the cork in the middle of the pan and wait until the cork stops moving.
2. Gently move the pan back and forth once or twice.
3. **Record Data** Record observations of the motion and final position of the cork in the data table.
4. Move the pan back and forth a little harder this time to create larger waves. Observe and record the motion and final position of the cork.
5. Clear your workspace. Using the spring toy, attach a small piece of modeling clay near the center of it. Mark the position of the clay on your workspace with a piece of tape.
6. Have a partner hold one end of the spring toy while you hold the other. Stretch the spring slightly so there is some tension. On your workspace surface, use two pieces of tape to mark the ends of the stretched spring toy.

7. Create several small pulses by repeatedly stretching the spring and returning the spring to its original position. Record observations of the motion and position of the clay once the waves stop.

8. Create larger pulses by repeatedly stretching the spring and returning the spring to its original position. Record your observations.

Observations		
	Motion	**Final Position**
Water/Cork—Small Waves	up and down	no change
Cork—Large Waves	up and down a greater distance	no change
Spring/Clay—Small Waves	back and forth	no change
Clay—Large Waves	back and forth a greater distance	no change

INQUIRY ACTIVITY

Communicate Information

9. How did the different waves move the objects? What patterns of motion did you notice?

Sample answer: The water waves moved the cork up and down. Its overall position did not change, though. The spring moved the clay back and forth, but its overall position did not change either.

10. Do your results support your prediction? How did the waves affect the movement of the cork and modeling clay?

Sample answer: Yes, the results supported my prediction. The cork and modeling clay moved, but their positions were not changed by the waves.

Talk About It

Discuss with your partner what causes wave movement, and how it is similar to earthquake movement.

MAKE YOUR CLAIM

How do the waves in the investigation compare to the seismic waves produced by an earthquake?

Make your claim. Use your investigation.

CLAIM

The waves in the water, the spring toy, and real-world earthquakes effect an object's motion by ____________________.

Sample answer: producing the same type of wave patterns.

Cite evidence from this lesson.

EVIDENCE

The investigation showed that the waves produced ____________________.

Sample answer: by the spring toy moved an object back and forth while the water waves moved the object up and down. Seismic waves produce longitudinal and transverse waves.

Discuss your reasoning as a class. Tell about your discussion.

REASONING

The evidence supports the claim because Sample answer: the energy released during an earthquake causes particles to vibrate in regular patterns of motion. The object's particles transfer the energy but do not travel in the direction of the wave.

You will revisit your claim to add more evidence later in this lesson.

VOCABULARY

Look for these words as you read:

amplitude

magnitude

seismic wave

seismograph

transverse wave

wavelength

Waves

What do the waves that you just modeled have to do with earthquakes? Earthquakes produce waves. Think back to the lesson phenomenon. The drop disturbed the surface when it hit the still water. The disturbance produced a series of circles that grew larger as they moved away from the center. These circles are waves. Recall that a wave is a disturbance that transfers energy from one point to another. Just like the drop of water, earthquakes produce waves that ripple outward from the place where the disturbance begins. The sudden movement of an earthquake causes rocks to vibrate. A vibration that travels through Earth and is produced by an earthquake is called a **seismic wave**. Seismic waves spread out in all directions from the focus, the point where an earthquake begins.

The movement of particles by waves is called vibration. Waves are classified by the type of vibration they cause in materials. Longitudinal waves, such as sound waves, move materials back and forth as the wave travels through it. You used the spring toy to produce longitudinal waves. A **transverse wave** is a wave that vibrates perpendicular to the direction that the energy moves. Transverse waves move material up and down as they travel. Earthquakes produce both longitudinal and transverse waves.

The way these students move the spring toy creates a transverse wave.

1. In what ways could you use a spring to model a transverse wave? A longitudinal wave?

Sample answer: I could model a transverse wave by moving the spring up and down or side to side. I could compress sections to model a longitudinal wave.

Features of Waves

The crest of a transverse wave is its highest point. In a longitudinal wave, it is the point where the particles are closest together. Waves also have troughs. The trough of a transverse wave is its lowest point. In a longitudinal wave, it is the point where the particles are farthest apart. For example, the highest point of an ocean wave is the crest, and the lowest point is the trough. Consider a boat on the water. As a wave goes by, the boat rises with the crest and falls with the trough. The boat moves up and down with the wave motion but it doesn't really move in any direction, except when it is close to the shoreline. **Wavelength** is the distance between wave crests or troughs. *Frequency* is the measure of how many crests or troughs move through a given point in one unit of time. High-frequency waves have shorter wavelengths and transfer more energy. The frequency and speed of a wave are not the same. The speed of a wave depends on the material through which it travels.

Amplitude is the height of a wave from its crest or trough to its midpoint. It is a measure of the wave's strength.

PRIMARY SOURCE

Scientists working on the ShakeAlert Earthquake Early Warning System. This system will help keep people safe when the next big earthquake occurs on the West Coast.

All waves transfer energy without permanently moving the material through which they travel. This means that after a wave has passed, particles end up in about the same position they started in.

2. Draw waves with the characteristics indicated below.

Long wavelength, low frequency:

Drawing should show same height peaks and narrower waves.

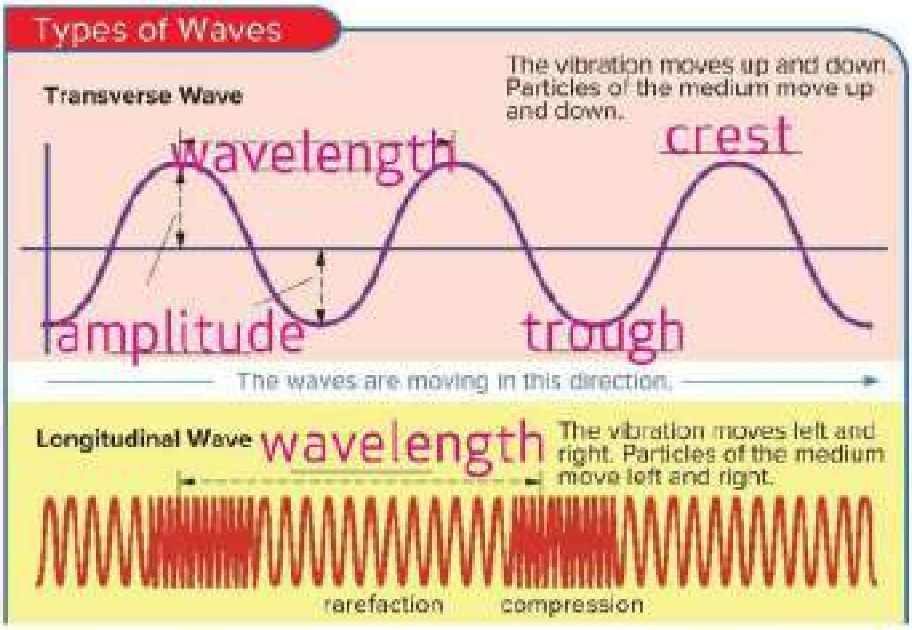
Short wavelength, high frequency:

Drawing should show same height peaks and wider waves.

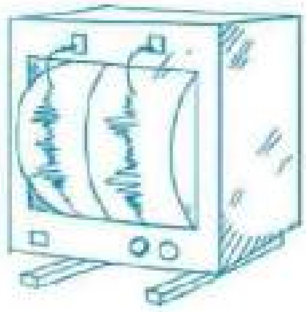
Label a Diagram: Parts of Waves

Use what you learned to label the wavelength, amplitude, crest, and trough of each wave.

GO ONLINE Watch the video *Earthquake Movement* to see how earthquake waves move.



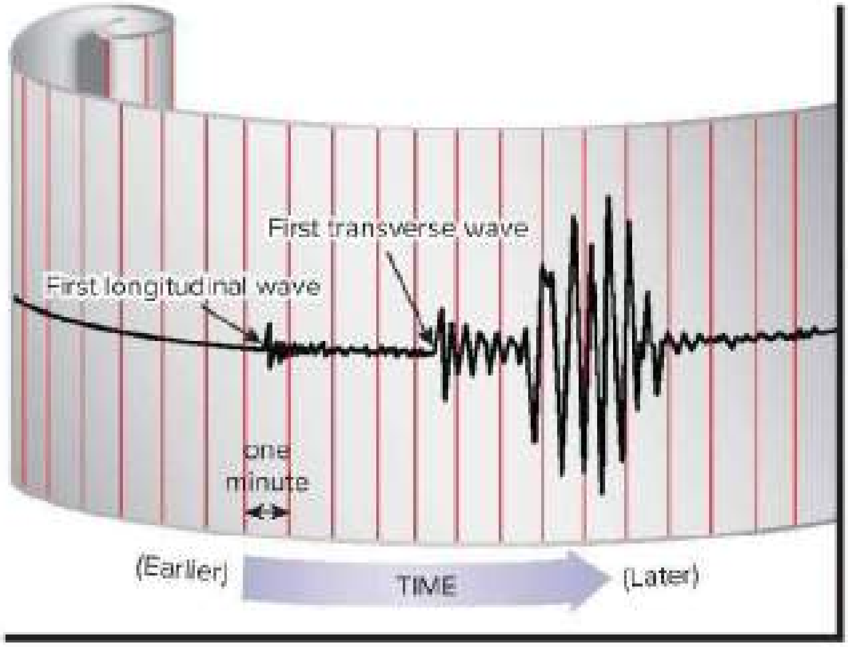
Record and Measure Earthquakes



Scientists measure seismic waves with a seismograph. A **seismograph** is an instrument used to detect and record earthquakes. The device shows the waves as curvy lines. The stronger the quake, the steeper the lines.

The amount of energy released by an earthquake is its **magnitude**. The Richter scale measures magnitude, the largest ground movement, when an earthquake occurs. It rates earthquakes from weakest to strongest starting at 1. Each larger whole number indicates that an earthquake has released 32 times more energy.

The Mercalli scale measures what people felt and what happened during an earthquake. It uses Roman numerals from I to XII.



3. What do you think happens to the amplitude of an earthquake wave when its magnitude increases?

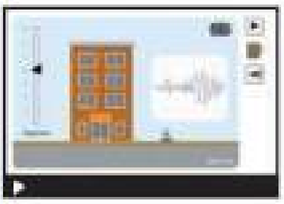
Sample answer: The amplitude of an earthquake wave increases as the magnitude increases.

INQUIRY ACTIVITY

Simulation

Earthquake Waves

An earthquake's energy is determined by the wave's frequency and amplitude. We label the amount of energy an earthquake's wave has as magnitude.



GO ONLINE

Use the simulation *Earthquake Waves* to complete the activity.

Now you will observe earthquakes of different magnitudes and see how they move the ground and buildings.

Make a Prediction What will happen to earthquake waves when the magnitude of the earthquake is increased?

Sample answer: The ground will shake more and buildings will show more damage as the magnitude of the earthquake is increased.

1. Observe the longitudinal and transverse waves as you use the slider to change their amplitude and frequency. Record your observations.

Sample answer: I noticed that when the amplitude was increased, the waves that were close moved even closer, while the parts where they were spread out became farther apart.

2. Investigate how earthquakes of different magnitudes affect buildings on Solid Rock. Use the slider bar to select an earthquake magnitude. Press the play button to set off the earthquake.
3. **Record Data** Test magnitudes 2, 4, 6, and 8. Use the camera button to take a picture of the effects for each of these magnitudes. Record your data in the table.
4. Repeat steps 2–3 to investigate the effects of earthquakes on buildings on Soil.

Observations				
Magnitude	Solid Rock		Soil	
	building	seismograph	building	seismograph
2				
4				
6				
8				

Students should observe that the damage to the buildings increases as magnitude increases. The seismograph records similar patterns for both types of surfaces at each magnitude. The building on soil shows more damage compared to the one on solid rock

Communicate Information

Using the notebook in the simulation, explain how you can **develop and use a model** to describe **patterns** of a wave's amplitude and wavelength. Use a drawing to support your response.

Sample answer: Drawings of waves can be used to describe earthquakes. The magnitude is shown as the amplitude of the wave. The pattern changes as the magnitude changes. An increase in magnitude results in an increase in amplitude.

Talk About It

Did your results support your prediction? Discuss with a partner.

COLLECT EVIDENCE

Use your observations as evidence to add to your claim from earlier in the lesson.

STEM Connection

How Could You Become a Seismologist?

Do you wonder how you can reduce the effects of an earthquake? If so, then seismology might be the field for you. Seismographs record the waves produced by earthquakes. **Seismologists** study these waves to look for patterns.

Seismologists study seismic waves and their effects on Earth in the past and the present. The black and white photos show the effect of an earthquake that occurred in Kern County, California in 1952. Seismologists use this data to help engineers design buildings that can better withstand the shaking caused by earthquakes.

Seismologists work with computers and other tools to collect and analyze data. Seismologists often find work in the petroleum industry, in government organizations, and at universities.

1952 Kern County, California earthquake

It's Your Turn

Like a seismologist, you will now analyze data from past earthquakes. Complete the activity on the next page to find out more about earthquakes of different strengths.

Historical Earthquakes in California

California has experienced a great number of earthquakes throughout its history. On a separate sheet of graph paper, plot the points in the table. Analyze and interpret your data to answer the questions below.

PRIMARY SOURCE

1994 Northridge, California earthquake

California Earthquake Data					
Year	**Location**	**Magnitude**	**Year**	**Location**	**Magnitude**
1906	San Francisco	7.8	1980	Eureka	7.2
1911	Calaveras Fault	6.5	1984	Morgan Hill	6.2
1920	Los Angeles	4.9	1989	Loma Prieta	6.9
1923	Cape Mendocino	7.2	1992	Landers	7.3
1933	Long Beach	6.4	1994	Northridge	6.7
1940	Imperial Valley	7.1	2004	Parkfield	6.0
1954	Arcata	6.6	2010	Baja	7.2

1. According to the data, which decade experienced the most earthquakes?

The 1980s experienced the most earthquakes.

2. What patterns can you identify in the intensity of past earthquakes?

About every 20 years, we have a major earthquake.

LESSON 2

Review

EXPLAIN THE PHENOMENON

How do water ripples model earthquake movement?

Summarize It

Use what you have learned to explain how the movement of water ripples is like the movement of earthquake waves.

Sample answer: The water ripples move in waves, just like earthquakes. They are a repeated motion that begins with a disturbance. The water ripples have wavelength and amplitude, just like earthquake waves. They move outward from the center in a repeating motion, just like earthquakes.

REVISIT PAGE KEELEY SCIENCE PROBES

Return to the Page Keeley Science Probe on page 87. Has your thinking changed? If so, explain how it has changed.

Three-Dimensional Thinking

1. What factors affect the speed of a wave?

Sample answer: The speed of a wave depends on the material through which it travels.

2. ________________ move material back and forth.

   A. Transverse waves
   B. Longitudinal waves
   C. Wavelengths
   D. None of the above

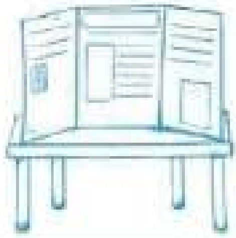
3. Why is it important to know the magnitude of an earthquake?

Sample answer: The magnitude helps seismologists measure the amount of energy released by the grinding of plates.

4. **MATH Connection** If a seismometer records an earthquake of 7.0 magnitude, how much energy is released compared to a 6.0 earthquake?

Sample answer: It would release 32 times more energy since each whole number on a Richter Scale is equal to 32 times more energy.

Extend It



You are a builder in your community. How might you communicate with the citizens about the effects of seismic waves on their homes?

Write a speech, draw a poster, create a flyer, or use media. Use the space below to write a draft.

Sample answer: First, I will present the history of earthquakes in the region. Second, I will explain to the citizens the types of waves present in earthquakes. Using a model, I will demonstrate which types of waves produce the most damage to their homes.

OPEN INQUIRY

What questions do you still have about seismic waves?

Sample answer: Have researchers found new information about how seismic waves affect structures?

Plan and carry out an investigation or research to find the answer to your question.

KEEP PLANNING

STEM Module Project
Engineering Challenge

Now that you have learned about earthquake movement, go to your Module Project to explain how the information will affect your plan for your building.

LESSON 3 LAUNCH

Shake, But Don't Fall

Earthquakes can cause human-made structures to collapse. Circle the boxes that are examples of things that can be done to reduce earthquake damage.

Designing buildings that can resist forces from the side.	Building only in areas where there has been no record of earthquakes.	Reducing the height of buildings in areas where earthquakes are most likely to occur.
Making the frame of a building less heavy by reducing the number of beams.	Connecting beams and columns with diagonal pieces.	Training people to seek shelter under doorways.
Adding fluids deep into the ground to prevent earthquakes from occurring.	Preparing for earthquakes by paying close attention to the weather.	Raising the floor of houses above ground when building near coastlines.

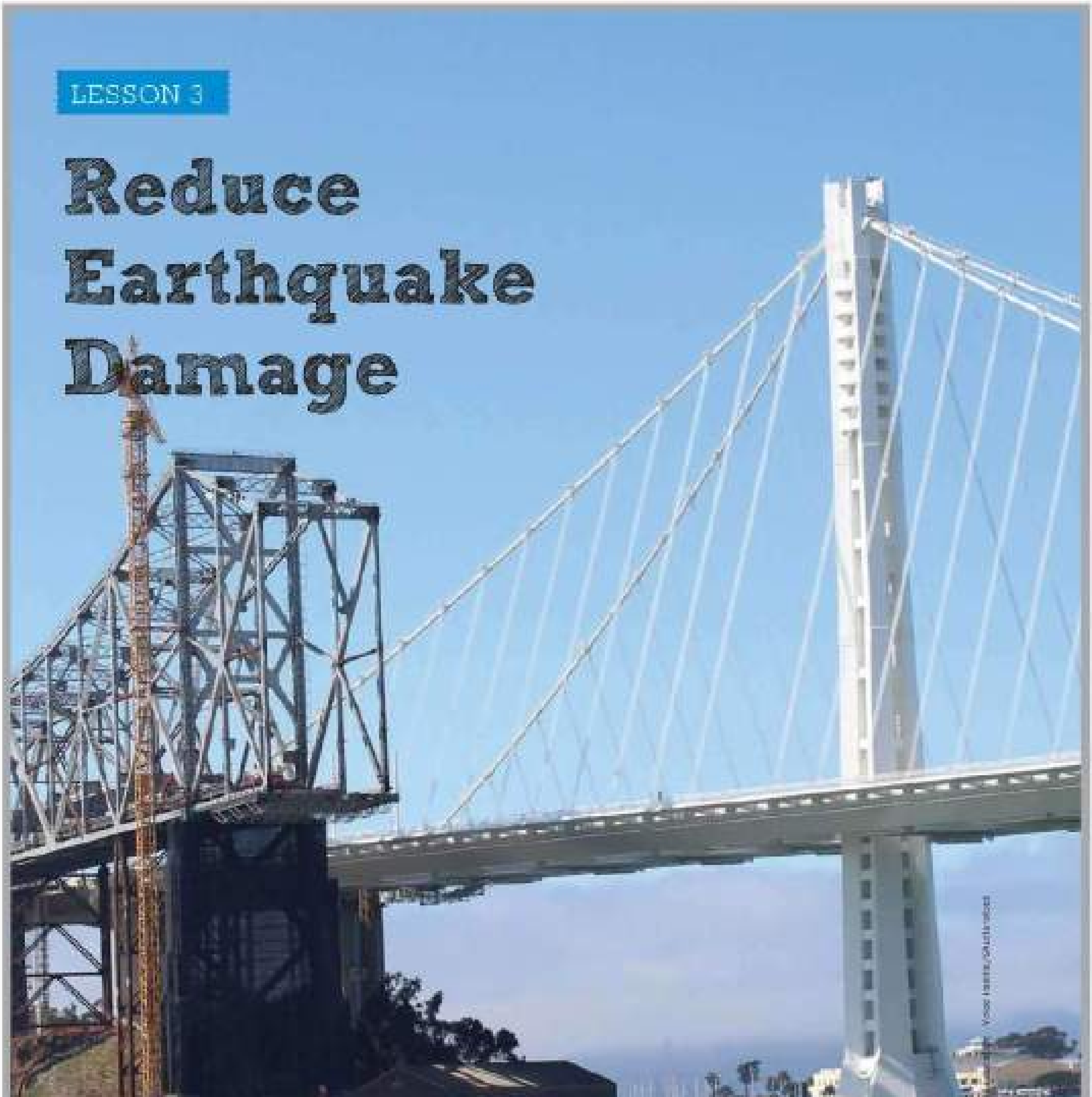
Explain your choices.

Sample answer: Designing buildings that can resist forces from the side and connecting beams and columns will help reinforce man-made structures. Also, raising the floor of houses above ground when building near coastlines will help reduce the effects of water damage caused by tsunamis.

You will revisit the Page Keeley Science Probe later in the lesson.

LESSON 3

Reduce Earthquake Damage



The original Oakland Bay Bridge was the longest bridge in the world when it opened in 1936.

ENCOUNTER
THE PHENOMENON

What features make structures resistant to earthquakes?

GO ONLINE

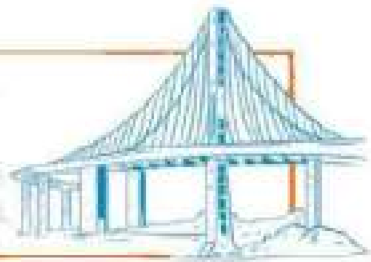
Check out *Bridges* to see the phenomenon in action.

Look at the photo and watch the video of the old and new eastern span of the Oakland Bay Bridge. What questions do you have about the phenomenon? Share your thoughts with a partner. Record or draw your thoughts below.

Sample answer: Why is the bridge being replaced? Why did they change its design? What features are similar to the old bridge? How would an earthquake affect its structure?

Did You Know?

The new eastern span of the Oakland Bay Bridge is suspended by one main cable made of 17,399 compressed wires. It's one of the largest spans of its kind in the world.



INQUIRY ACTIVITY

Hands On

Earthquake Effects

You have learned about how earthquake waves move.

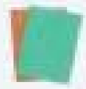
Make a Prediction What effect does the motion from an earthquake have on roads and buildings?

Sample answer: The motion from an earthquake has the ability to knock buildings down and break roads apart.

Materials


tape


2 identical textbooks


construction paper


colored pencils


blocks


four smooth pencils

Carry Out an Investigation

1. Tape a piece of construction paper to the cover of each textbook.
2. Place the books next to each other on a desk, spine to spine. Place two smooth, round pencils under each book, spaced so the books roll easily. Draw a "road" that crosses from one piece of construction paper to the other.
3. Use the blocks to construct a small "house" where the books meet.
4. Slowly and gently shake the desk to model an earthquake.
5. Record your observations by drawing a sketch and labeling the details of what you observed.

Students should indicate that the books and blocks moved slightly. The road may break. A few blocks may fall over.

6. Line up the road and rebuild your house to match its appearance in step 3.
7. Shake the desk rapidly and with more force. Observe what happens to the road and the house.

8. Record your observations by drawing a sketch and labeling the details of what happened.

Sample answer: The books will separate even more. The blocks will likely topple over and the road will break.

Communicate Information

9. What effect did the motion have on the roads and building? Use evidence to explain whether the results support your prediction.

Sample answer: The motion I observed broke the roads and building. This supports my prediction.

What **causes** earthquakes? How would you **design a solution** that prevents your house from breaking? Draw your design below.

Sample answer: I could use different flexible materials to allow parts to move without breaking.

Talk About It

What can be done to prevent earthquake damage? How could earthquakes damage a bridge? Share your ideas with a small group.

VOCABULARY

Look for these words as you read:

bracing

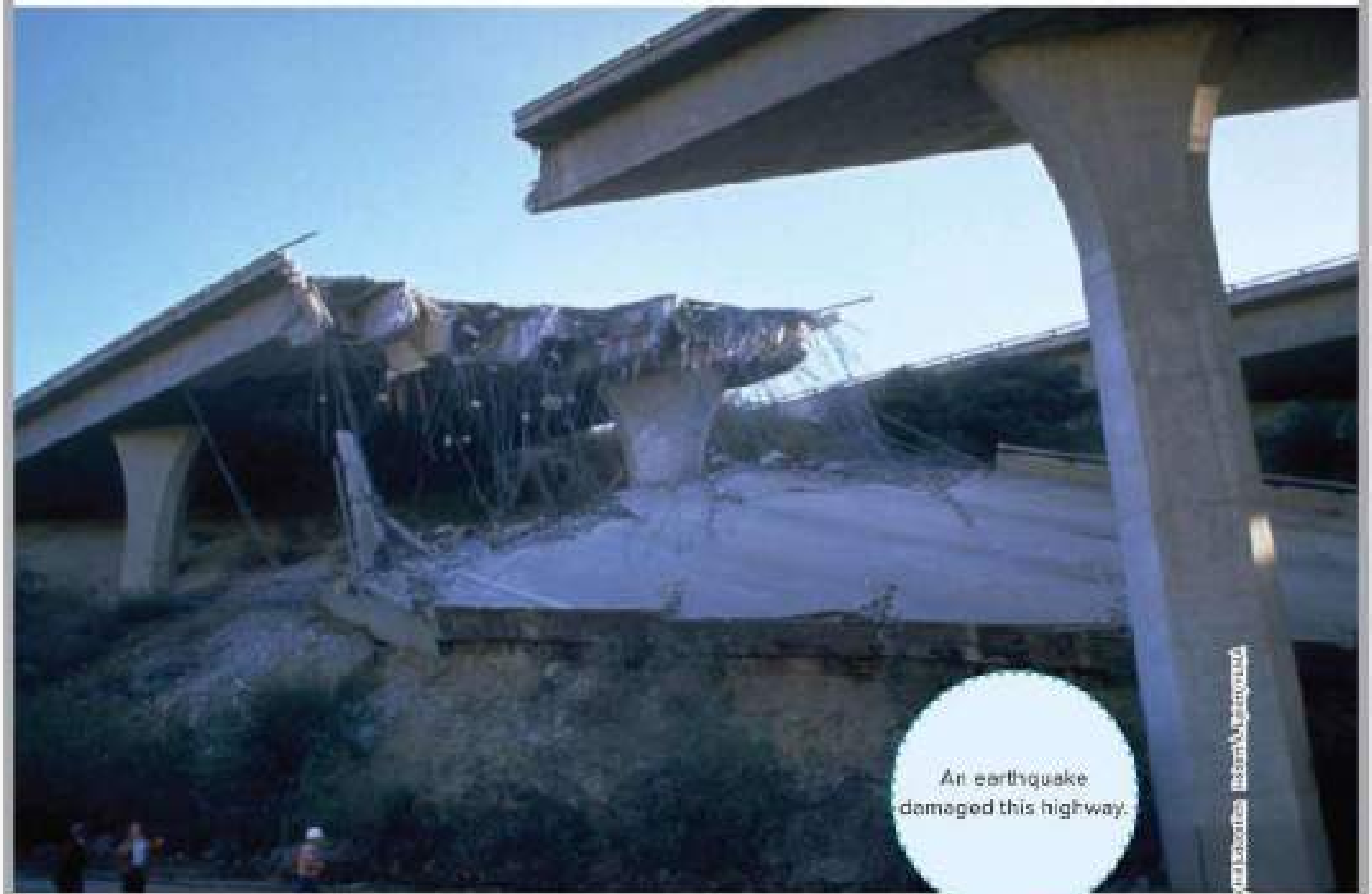
lateral force

shear wall

Predict Earthquakes

Most earthquakes are too weak to be noticed. Others cause extreme damage. During a major earthquake, buildings and roads might break apart. Bridges might collapse.

Seismologists use seismometers to identify and map the epicenters of earthquakes. Then they compare the epicenter location to known fault locations. They use this information to describe how rock along the faults has moved over time. They watch faults to let people know about the threat of possible earthquakes.



An earthquake damaged this highway.

1. Why do seismologists watch faults?

Sample answer: They watch faults in order to detect possible earthquakes.

Earthquake Signs

A bulge or change in the angle of the ground is a sign that an earthquake is likely to occur. But even with these signs, it is difficult to predict how soon an earthquake will occur. It could be hours, days, weeks, or months before enough energy builds up for the ground to shift.

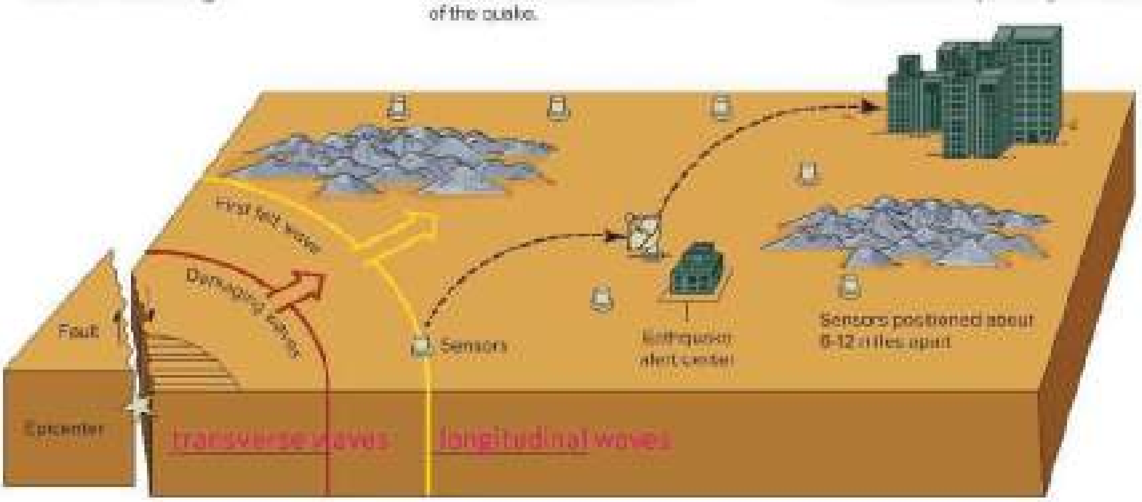
New technology can warn people that an earthquake is coming. The warning gives people seconds, or minutes, notice of an earthquake's arrival. This technology works by first detecting longitudinal waves from a break at a fault. The sensors then analyze the data to determine the location and size of the earthquake. The system sends a message stating the intensity and arrival time of the earthquake.

Label a Diagram: Earthquake Warning

Recall the information from Lesson 2 about how seismographs record seismic waves. Label the longitudinal wave and transverse wave in the diagram.

Earthquake Early Warning Basics

1. In an earthquake, longitudinal waves move the fastest. Transverse waves arrive later but cause more damage.
2. Sensors detect the longitudinal wave and transmit data to the earthquake alert center to determine the location and size of the quake.
3. A message is sent to your electronic device, which calculates the expected intensity and arrival time of the earthquake at your location.



Earthquake Safety

You can stay safe during an earthquake by following a few simple rules. If you are indoors, duck under a table or doorway. Keep away from walls and windows. If you are outdoors, stay away from trees, power lines, and any structures that might fall down.

People cannot stop an earthquake from occurring, but they can take steps to reduce the damage it causes. Secure objects in your house that might fall if you live in an earthquake-prone area. You can also identify safe places to use as shelter during an earthquake.

Many of the objects in this house were moved or broken during the earthquake.

1. Why should you get under a sturdy table to stay safe in an earthquake?

Sample answer: The door frame or table will block objects from falling on you.

Safe Structures

Certain building materials can help a structure stand up to earthquakes. Materials such as bricks and concrete blocks crumble easily when shaken. Reinforced concrete, metal, and wood work better because they can be tied to other parts of the structure and do not crumble.

Shorter buildings might be less likely to be damaged in an earthquake, but tall buildings can also remain stable during an earthquake. Very tall buildings are more flexible than shorter buildings. Buildings that are more flexible are less likely to collapse.

Placing layers of rubber and steel, or motion dampeners, at the base of bridges can reduce damage from earthquakes. Some of these motion dampeners act like the shock absorbers in a car. Sections of bridges can be joined by rubber joints that allow the bridge to sway during an earthquake. The rubber joints make bridges more flexible.

Another safety feature can be seen in the east span of the Oakland Bay Bridge. It suspends by a single cable from a main tower. The main tower is made up of four concrete towers designed to flex and remain intact through the strongest earthquakes.

Reinforced concrete has metal pieces inside that tie it together and keep it from breaking with movement.

This new Oakland Bay Bridge is more like a swing. Its single cable loops under the road and over its main tower.

2. How can a structure be made more earthquake-resistant? Name two ways.

Sample answer: Use reinforced concrete, metal, and wood instead of bricks or blocks. Use layers of rubber and steel beneath the structure to absorb movement from earthquakes.

CLOSE READING

Inspect

Read this passage from the Investigator article *Designing Strong Buildings.* Underline text evidence that tells how bracing supports an earthquake-resistant building.

Find Evidence

Reread Highlight text evidence that tells how buildings can resist lateral forces.

Notes

Designing Strong Buildings

Architects and scientists study earthquakes to design safe buildings. A building needs to resist lateral forces during an earthquake. **Lateral forces** are forces that come from the side. Buildings have steel, wood, or concrete frames. Horizontal beams support the weight of roofs and floors.

Beams transfer forces to vertical columns. Columns transfer forces to the foundation. The foundation transfers forces to the ground. The frame of a building can resist lateral forces with bracing. **Bracing** is made of diagonal pieces connecting beams and columns. Bracing comes in several shapes. Some bracing looks like the letter X. Other bracing looks like the letter K.

This building's frame has X bracing. Bracing can also look like the letter K.

This skyscraper in Taiwan was designed to withstand earthquakes.

Buildings can also resist lateral forces with shear walls. A **shear wall** is a stiff wall made of braced panels. Some tall buildings have a shear core. A shear core is usually a stairwell or elevator shaft with a shear wall on each side. Architects and engineers determine the size of a shear wall based on their calculations of potential lateral forces.

Another way for very tall buildings to resist lateral forces is with a damper. The damper is a mass that can weigh over a million pounds. It is attached to the building on the inside of the top floors, but it moves independently from the building. The damper makes the building move less from lateral forces.

How do bracing and shear walls help a building?

Sample answer: Bracing and shear walls help a building to stand up to the lateral forces of an earthquake.

This building has a 728-ton damper that helps it resist movement. The damper hangs between the 87th and 92nd floors.

GO ONLINE Watch the video *Earthquake Damage* to see more earthquake-resistant building features.

REVISIT PAGE KEELEY SCIENCE PROBES Revisit the Page Keeley Science Probe on page 105.

Make Connections

Talk About It

How could a structural engineer and cartographer work together when building earthquake resistant buildings?

Notes

STEM Connection

Emergency Management Specialist

This emergency management specialist is helping people that were impacted by an earthquake.

Have you ever been in an emergency? Who helped you? Where did you go to stay safe? You might have been helped by a police officer or a medical doctor—there are many types of people who help in an emergency. But what if this emergency involved a natural disaster, like an earthquake? That is where you would receive help from me! I am an **emergency management specialist**, and I help people during emergencies, such as earthquakes, tsunamis, and floods.

It is so rewarding to help people in need! Today I helped coordinate the delivery of food, water, and medicine to the victims of an earthquake in southern California. I also helped to set up shelters for those who had lost their homes. The victims were so grateful for help.

Not every day is as eventful as today, but we are constantly preparing for days like this. Sometimes I review emergency evacuation routes to make sure they are the most efficient. I help organize emergency response teams to respond quickly when natural disasters occur. I also help communities that have been hit by a natural disaster apply for emergency funds.

Emergency management specialists like me help people throughout an emergency. Most of the time we are in the preparing stage. It takes lots of planning to prepare for emergencies. Immediately after a natural disaster, we respond. In the days and months following, we help the people recover and then rebuild.

It's Your Turn

Think like an emergency management specialist. Complete the activity on the next page to research additional ways to reduce earthquake damage in your community.

Talk About It

How would an emergency management specialist help prepare for future earthquakes?

INQUIRY ACTIVITY

Research

Earthquake-Resistant Structures

One way that people can prepare for earthquakes is by building earthquake-resistant structures that will keep people safe. How are buildings near you designed to resist earthquake movement?

In this activity, you will research two different earthquake-resistant structures found in cities near you. You will report your results in a television news story about how the designs keep people safe.

Ask a Question What question will you answer with your research?

Sample answer: What features make man-made structures resistant to earthquakes?

Carry Out an Investigation

1. Select two earthquake-resistant structures found in cities near you.
2. Research the two different structures. Identify the design features that help them stand up to the motion of an earthquake.
3. Sketch the two structures below. Label the features that help each structure resist earthquake movement.

Structural engineers design earthquake-resistant structures like this treated water storage tank.

Students should sketch each structure and label the support and motion dampening in each drawing.

4. How does each of the design features keep people safe?

Sample answer: The bracing holds beams and columns together and makes the building stronger. The motion damper absorbs motion so that bridges can flex and remain standing.

5. How do the two structures compare?

Sample answer: Both structures use a motion damper beneath their foundation.

6. Use your research to prepare a news story to present to the class. Be sure to use visuals to help explain your results. Use the space below to plan your presentation.

Students should outline their presentation in a logical way, using visuals to support their explanations.

What do the **structure and function** of your design features have in common with earthquake-resistant buildings near you? Use evidence from your research to **construct your explanation**.

Sample answer: Bracing, shear walls, and motion dampers are common in both because they absorb the motion of an earthquake.

Talk About It

What other features would you invent to improve the chances of a structure resisting an earthquake? Share your thoughts with a partner.

LESSON 3

Review

EXPLAIN THE PHENOMENON

What features make structures resistant to earthquakes?

Summarize It

Explain how structures can be designed to reduce earthquake damage.

Sample answer: Structures can be constructed of strong but flexible materials that allow them to sway but not break during an earthquake. Structures can use different types of motion-dampening devices to resist movement. Buildings can include bracing, shear walls, and shear cores which can help them resist lateral forces.

REVISIT PAGE KEELEY SCIENCE PROBES

Return to the Page Keeley Science Probe on page 105. Has your thinking changed? If so, explain how it has changed.

Three-Dimensional Thinking

1. What patterns did you notice in earthquake-resistant structures?

Sample answer: Longer bridges and taller buildings are more flexible because they include more rubber joints and more bracing in their design.

2. How does knowing about earthquake waves help engineers design safer structures in a lab?

Sample answers: Engineers can test different materials and designs by simulating seismic waves in a lab to predict if the design will withstand earthquake waves.

3. ______________ is made of diagonal pieces connecting beams and columns. It comes in several shapes.

A. A lateral wall

B. A damper

C. A shear wall

D. Bracing

Extend It

You are an emergency management specialist in your community. How might you communicate with your citizens about proper precautions to reduce earthquake damage?

Write a speech, draw a poster, create a flyer, or use media.

Sample answer: I would use media to show citizens different ways of staying safe during an earthquake and ways to protect their home from earthquake damage.

KEEP PLANNING

STEM Module Project
Engineering Challenge

Now that you have learned about reducing earthquake damage, go to your Module Project to explain how the information will affect your plan for your building.

STEM Module Project
Engineering Challenge

Design an Earthquake-Resistant Building

You've been hired as a structural engineer. Using what you have learned throughout this module, you will develop two designs for a school. Your goal will be to work with a small group to design, build, and test your models of a school building to see if they are able to resist the forces of an earthquake. You will compare the results of the test and select the design that best minimizes earthquake damage.

Planning after Lesson 1

Apply what you have learned about earthquakes and where they occur to your project planning.

How does knowing where earthquakes occur affect your project planning?

Sample answer: I could work with a cartographer who has mapped where earthquakes occur in the area where I plan to build so I can determine the best location and prepare my design.

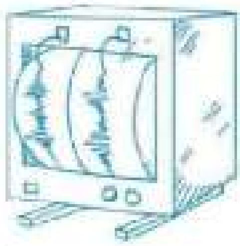
STEM Module Project
Engineering Challenge

Planning after Lesson 2

Apply what you learned about how earthquakes move to your project planning.

What factors should be considered when building your models?

Sample answer: I will need to design the buildings to withstand both horizontal and vertical motion. I also need them to withstand earthquakes of varying magnitudes.



Planning after Lesson 3

Apply what you learned about preparing for earthquakes to continue your project planning.

What design features will you use in your models to help it withstand earthquake forces?

Sample answer: I will use bracing and shear walls to help my model buildings withstand the forces of an earthquake.

Research the Problem

Read the Investigator article *Designing Strong Buildings*.

Research building designs and the strengths of various geometric shapes by going online to teacher-approved websites, or find books on strong building designs at your local library.

Source	Information to Use in My Project
Sample answer: Investigator article, various online sources	Using horizontal beams, different types of bracing, and shear walls to support the structure. Triangles are the strongest shape.

Sketch Your Model

MATH Connection Draw your ideas in the space below. Use different colored pencils to identify parallel lines, perpendicular lines, and angles (right, acute, obtuse). Select two models to build and test.

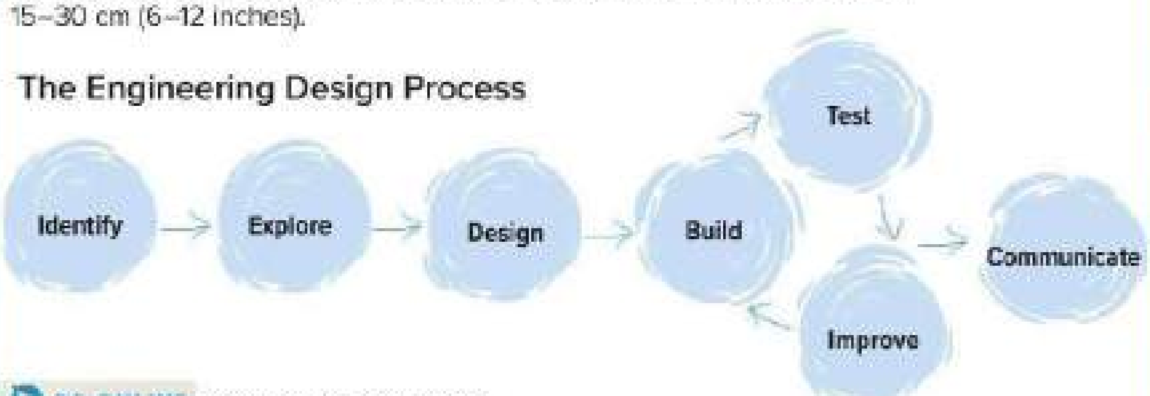
Students' drawings will vary. Drawings should show two models with different features that allow buildings to resist earthquakes or reduce damage.

STEM Module Project
Engineering Challenge

Design an Earthquake-Resistant Building

Look back at the planning you did after each lesson. Use that information to complete your final module project. As part of the design criteria, your models must remain standing after being placed on a table and shaken for 15 seconds. The constraint is that your model must measure between 15–30 cm (6–12 inches).

The Engineering Design Process



GO ONLINE to learn more about each step of the *Design Process*.

Build Your Model

1. Determine the problem you are trying to solve with your models.
2. Determine the criteria for your models, and list the materials you will use to build your models.
3. Use your project planning to build your models.
4. Record the steps of your procedure to carry out a fair test of your models.
5. Use the results of your test to compare your two models. Then select the design that best meets the criteria and constraints of the project.

Materials

Students will determine their materials.

Procedure: 1. Make eight equally sized balls of clay; 2. Cut eight straws into 15 cm (6-inch) lengths; 3. Cut four of the straws in half; 4. Insert each longer straw into a ball of clay and stand it upright; 5. Connect the shorter straws to the clay to form the bottom of the model; 6. Place a ball of clay on top of each straw, then repeat step 5; 7. Cut cardboard to fit the sides and top of the frame; 8. Tie the cardboard pieces to the side and top of the frame with string; 9. Place model in the center of a desk. Test by shaking desk for X minutes. Observe what happens to the model; 10. Use what was observed to improve the design. Test the improved model and observe.

Test Your Model

Record your observations and results. Use a data table or separate sheet of paper if needed. Select the design that best meets the criteria and present it to your class.

Model one test: I shook my model and observed that three of the straws on top of the model had come out of the clay. The building was leaning to one side, too.

Model two test: I used more straws to brace the sides of the building. I also used more clay where the straws met. I shook the model for the same amount of time and with the same amount of force as the first test. I checked the model after shaking. It was not leaning. When I looked at the straw frame inside, I saw that all of the straws had stayed in place.

STEM Module Project
Engineering Challenge

Communicate Your Results

Share the plan for your models and your results with another group. Compare how well each of your models was able to meet the criteria of withstanding the force of an earthquake. Discuss how well your models met the criteria and constraints, and identify ways you can improve your models. Communicate your findings below.

Sample answer: Some classmates used stronger materials, like craftsticks and glue. Their models worked better than mine; they both met the criteria. Another group used paper and tape. Their model was not as strong as my models. They had to brace their models with cardboard to help it withstand the shaking. I think if I used straws and craftsticks, then I could make a really strong model that would withstand an earthquake.

MODULE WRAP-UP

REVISIT THE PHENOMENON

Using what you have learned in this module, explain why this building collapsed, but the others did not.

Sample answer:
My module project showed me that I had to think of the stability of the base of my building so that it could withstand the effects of an earthquake. This building collapsed because it was not designed to be earthquake-resistant.

Revisit your project if you need to gather more evidence.

How has your thinking changed? Explain.

I now know that engineers can design earthquake-resistant structures that can reduce the damage of seismic waves.