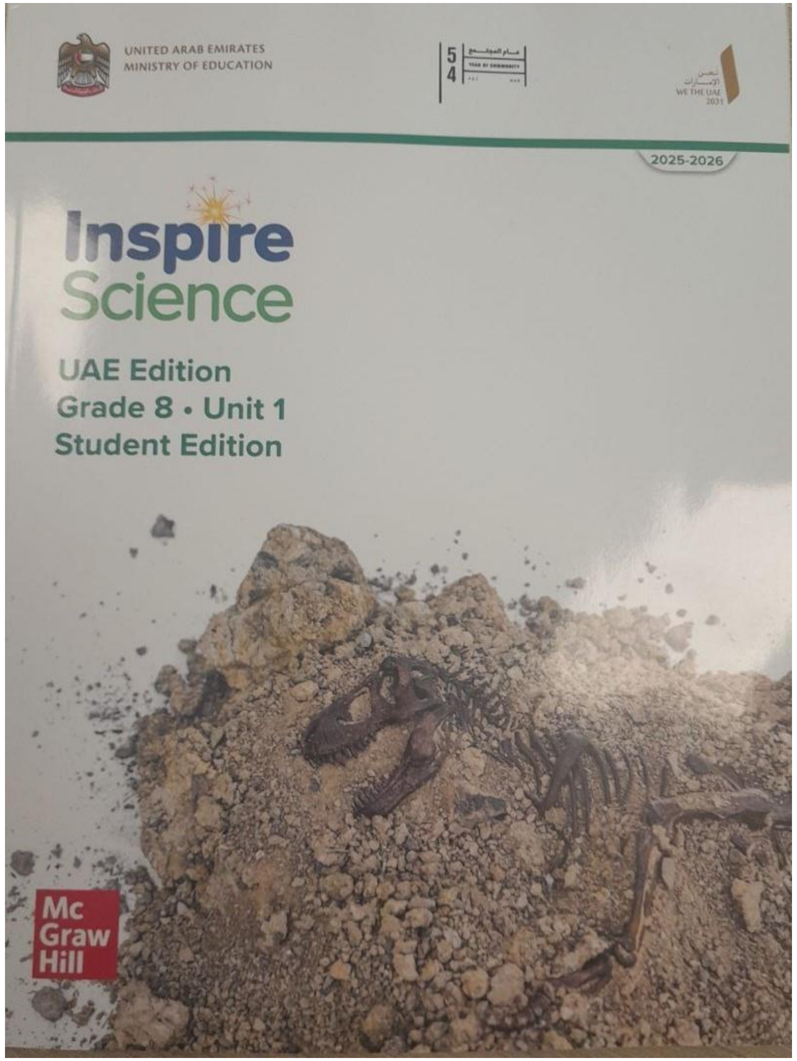
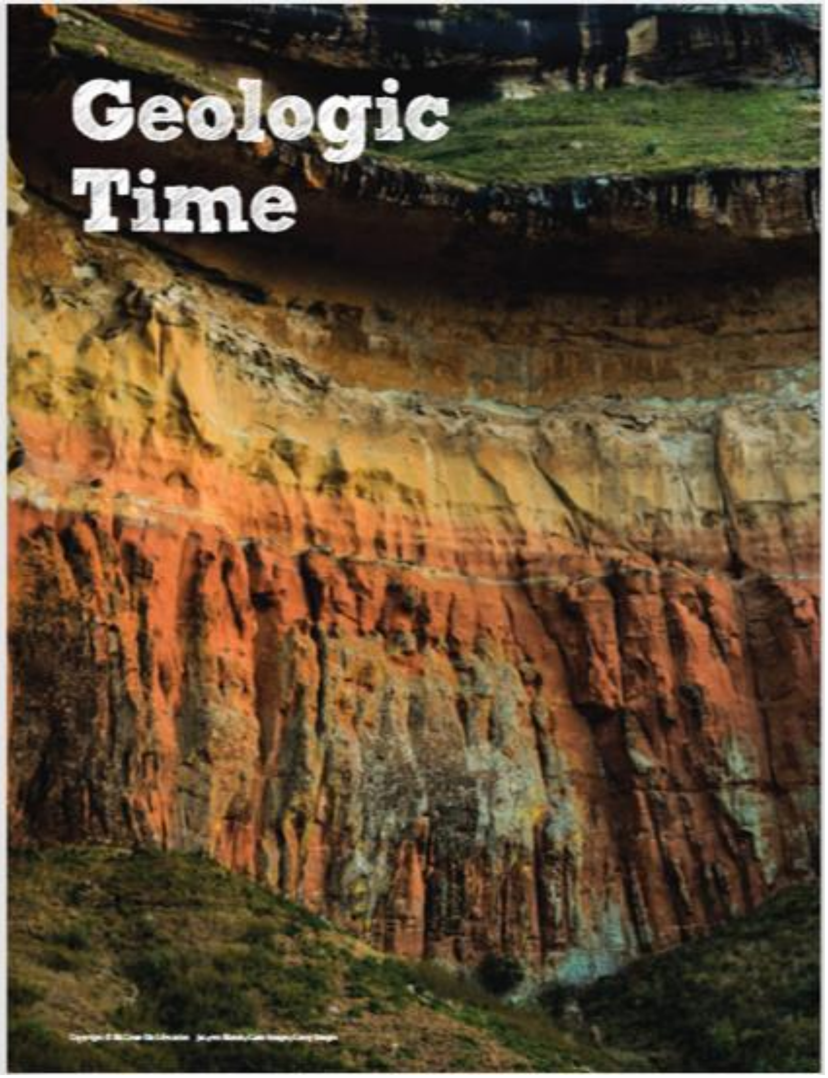
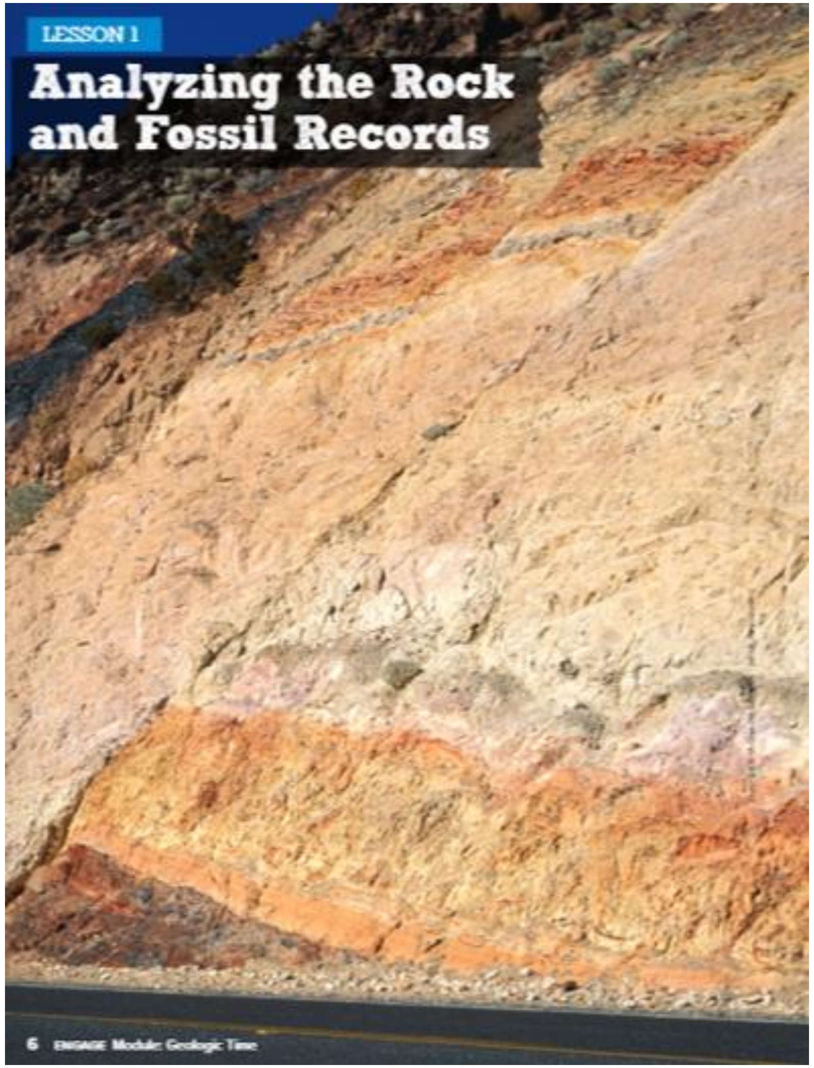
Unit 1



Module 1



Lesson 1



Key Vocabulary

1. Uniformitarianism
2. Absolute age
3. Relative age
4. Superposition
5. Original horizontality
6. Lateral continuity
7. Inclusions
8. Cross cutting relationships
9. Fossils
10. Mass extinctions

ENCOUNTER THE PHENOMENON

How can the rock layers and geologic features in this photo be used to sequence past geologic events?

GO ONLINE
Explore the *Shoshone Road Cut* to see this phenomenon in action.

What did you notice as you explored the photo online? Try to identify distinct parts of the image and then focus on one part at a time. Record your observations in the space provided. How might you determine which layers and features are older than others? With your partner, discuss the clues you might use to determine the sequence of the past geologic events that created this landscape.

the light-colored rock layers are offset by two normal faults. The rock layers to the left of the faults have moved down in relation to the the rock layers to the right of the faults.

the dark conglomerate layer that tops the sequence, and the black band (a vitrophyre) to the left of the faults.

the rocks had to be in place prior to faulting, therefore the rocks are older than the faults. Using clues such as cross-cutting relationships allows geologists to determine the relative ages of rocks and features.

EXPLAIN THE PHENOMENON

Are you starting to get some ideas about the clues geologists use that enable them to read rock layers like pages in a history book? Use your observations about the phenomenon to make a claim about how the order of geologic events can be determined.

CLAIM

The sequence of past geologic events can be determined by...

COLLECT EVIDENCE as you work through the lesson. Then return to these pages to record your evidence.

EVIDENCE

A. What evidence have you discovered to explain how the rock record provides relative ages?

MORE EVIDENCE

B. What evidence have you discovered to explain how the fossil record provides relative ages?

When you are finished with the lesson, review your evidence. If necessary, based on the evidence, revise your claim.

REVISED CLAIM

The sequence of past geologic events can be determined by...

Finally, explain your reasoning for how and why your evidence supports your claim.

REASONING

The evidence I collected supports my claim because...

What is the basis for understanding Earth's past?

Early ideas about Earth's age and geologic history were usually placed in the context of time spans that a person could understand relative to his or her own life. This changed as people began to explore Earth and Earth processes in scientific ways. Today, scientists know that Earth's history stretches back 4.6 billion years. When did this change of thought occur, and how?

INVESTIGATION

The Present Is the Key to the Past

Compare the images of erosion below.


1. Do you think the processes that form and shape the small stream bed are similar to those that form and shape the Grand Canyon? Why or why not?

Yes. The water erosion that is wearing away the banks of the stream is the same as the erosion that is carving the Grand Canyon.

2. How long do you think it would take to create a canyon as deep as the Grand Canyon? Explain your reasoning.

: Millions of years. Much longer than the lifetimes of humans or the entire history of humanity.

Want more information?
Go online to read more about how scientists analyze the rock and fossil records.

FOLDABLES
Go to the Foldables® library to make a Foldable® that will help you take notes while reading this lesson.

Principle of Uniformitarianism Before the late 1700s, most people thought that Earth was only a few thousand years old. James Hutton rejected this idea. He was one of the first scientists to think of Earth as very old. Hutton was a naturalist and a farmer in Scotland. He observed how the landscape on his farm gradually changed over the years. Hutton thought that the processes responsible for changing the landscape on his farm could also shape Earth's surface. For example, he thought that erosion caused by streams on his farm could also wear down mountains or carve deep canyons. Because he realized that this would take a long time, Hutton proposed that Earth is much older than a few thousand years.

Hutton's ideas are the foundation of a principle called uniformitarianism. The principle of **uniformitarianism** states that geologic processes that occur today are similar to those that have occurred in the past. In other words, the same processes that we see today have been occurring since Earth formed.

THREE-DIMENSIONAL THINKING

Scientists use the principle of uniformitarianism to **Interpret** Earth's history. Suppose you discover a rock from an ancient beach. Now imagine you are standing on that ancient beach. What do you think you would you see? **Explain** how your answer relates to the principle of uniformitarianism.

If you stand on a shore of an ocean and watch the waves come in, you are observing a process that has not changed since the oceans formed. Using the principle of uniformitarianism, you can infer that you would see waves eroding the shore of the beach just as they do today.

Because of uniformitarianism, scientists can learn about Earth's past by studying the present. One way to do this is by studying the order in which geologic events occurred using a method called relative-age dating. This does not allow scientists to determine the **absolute age**, or the actual age of the events. But it gives scientists a clearer understanding about geologic events in Earth's history.

What is relative-age dating?

Geologists—the scientists who study Earth and rocks—use rock layers and the fossils within to build a record of Earth's geologic history. How do rock layers form? Remember that weathering breaks rocks exposed at Earth's surface into smaller pieces called sediment. Over time, gravity, water, and wind carry sediment downhill and deposit it in low areas. Eventually, layers of sediment form. The increasing weight of the sediment slowly causes the layers to compress, forming layers of rock called strata.

Can you model rock layers?

What do you think happened to these rock layers?

LAB Layers Rock

Safety

Materials

disposable polystyrene meat trays (3)

Procedure

1. Read and complete a lab safety form.
2. Work in groups of 3–4.
3. Break a meat tray in half. Place the two pieces on a flat surface so that the broken edges touch one another.
4. Break another meat tray in half in the same way so that the break is consistent between the two meat trays. Place the two pieces directly on top of the first broken meat tray.
5. Place a third, unbroken meat tray on top of the two broken meat trays. Sketch your model below.

6. Follow your teacher's instructions for proper cleanup.

Analyze and Conclude

7. How do you think your model resembles a rock formation?

The model resembles a rock formation of sedimentary rock because it is in layers. Sometimes rock layers are broken, or faulted, like the model.

8. If you observed rock layers that looked like your model, what would you think might have caused the break only in the two bottom layers? Why might the top layer not be broken?

The bottom layers were likely disturbed by a fault—a break or fracture in rocks. The top layer is not broken because it was deposited after the disturbance occurred.

9. Which layer in your model do you think is the youngest? Which do you think is the oldest? Explain your reasoning.

The top layer is the youngest. The bottom layer is the oldest. The bottom layer was there first, making it older. Layers that were deposited later are on top of the initial layer, making them younger.

Relative Age In the *Layers Rock* lab you interpreted the ages of the layers in comparison to each other. This is called relative age. **Relative age** is the age of rocks and geologic features compared with other rocks and features nearby.

Geologists have developed a set of principles to organize rock layers according to their relative ages. Using the principles of relative-age dating, geologists can determine if rocks or features are younger or older than the rocks or features around them. Let's investigate.

Relatively Speaking

Analyze the image below.

1. Do you think all of the rock layers in the picture formed at the same time? Why or why not?

No. sedimentary rock forms slowly over time. The sediments must be compressed and lithified before they turn into rock layers. The colors of the layers also indicate differences between the rocks.

2. If you think the rocks formed at different times, which layers are the oldest and which are the youngest? Explain.

The rock layers at the bottom of the formation are the oldest. The rock layers get younger as you go up. Each layer had to form on top of the last one deposited, making each layer younger than the one before.

Now, study this image.

3. Do you think the small pieces of rock in the picture formed at the same time as the rock containing the pieces? Why or why not?

No. The small pieces of rock must have formed before they were incorporated into the rock shown here.

4. If you think the rock formed at different times, which is oldest—the rock containing the pieces, or the pieces of rock? Explain.

The small pieces of rock are older than the rock containing the pieces. The pieces of older rock became part of the new, younger rock sometime in the past.

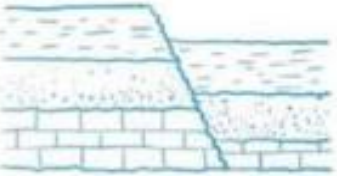
Now, try to interpret this image.

5. Notice the large fault cutting across the rock layers. Do you think the fault and the rock layers are the same age? Why or why not?

No. The rock layers formed slowly over time. The fault cuts across all of the layers. This could not have occurred while the rock layers were forming.

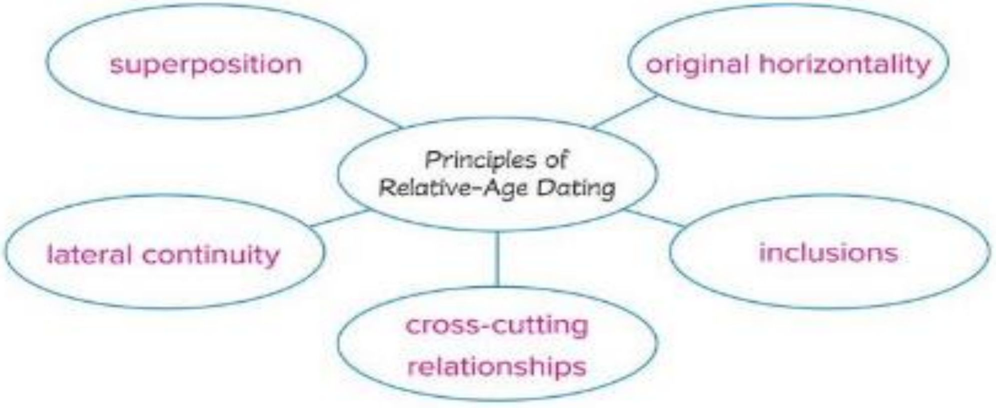
6. If you think the fault and the rock formed at different times, which is oldest—the fault or the rocks? Explain.

The rocks are older than the fault. The rock layers had to form first. Sometime after that, a fault broke through the rock layers.



GO ONLINE Finally, watch the animation *Relative-Age Dating.* Then answer the questions that follow.

7. What are the principles of relative-age dating?



8. Which principle did you apply in Step 2 of the investigation?

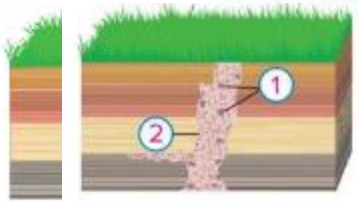
superposition

Using this principle, assign the rock layers in the diagram to the right their relative ages from oldest (*1*) to youngest (*4*).

9. Which principle did you apply in Step 4 of the investigation?

inclusions

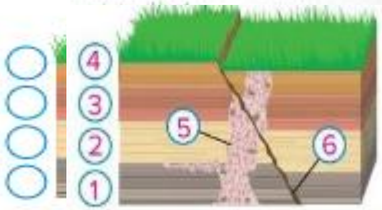
Using this principle, label the older feature *1*, and the younger feature *2* on the diagram to the right.



10. Which principle did you use in Step 6 of the investigation?

cross-cutting relationships

Using this principle, label the rock layers and features from oldest (*1*) to youngest (*6*).



The Principles of Relative-Age Dating As you just discovered in the *Relatively Speaking* investigation, there are five principles that geologists use to assign relative ages to rocks and features.

- **Superposition** is the principle that in undisturbed rock layers, the oldest rocks are on the bottom.
- According to the principle of **original horizontality,** most rock-forming materials are deposited in horizontal layers.
- **Lateral continuity** is the principle that sediments are deposited in large, continuous sheets in all lateral directions.
- According to the principle of **inclusions,** if one rock contains pieces of another rock, the rock containing the pieces is younger than the pieces.
- According to the principle of **cross-cutting relationships,** if one geologic feature cuts across another feature, the feature that it cuts across is older.

THREE-DIMENSIONAL THINKING

Models are often used to study and represent **large-scale** time and space phenomena. Using what you have learned about the principles of relative-age dating, create a sketch modeling each principle below.

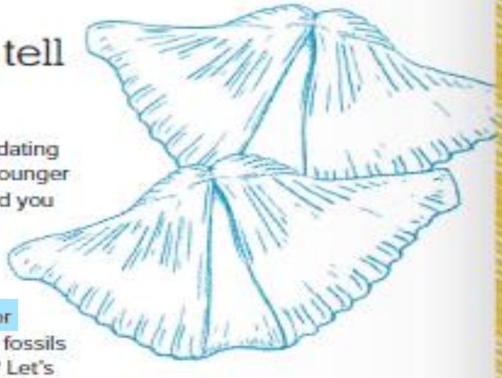
understanding of superposition, original horizontality, lateral continuity, inclusions, and cross-cutting relationships

Rock layers at the bottom are typically older than the layer at the top. inclusions, faults, cross cutting are some of the examples of relative age dating.

COLLECT EVIDENCE

How do the principles of relative-age dating help scientists "read" rocks? Record your evidence (A) in the chart at the beginning of the lesson.

What can the fossil record tell us about Earth's history?



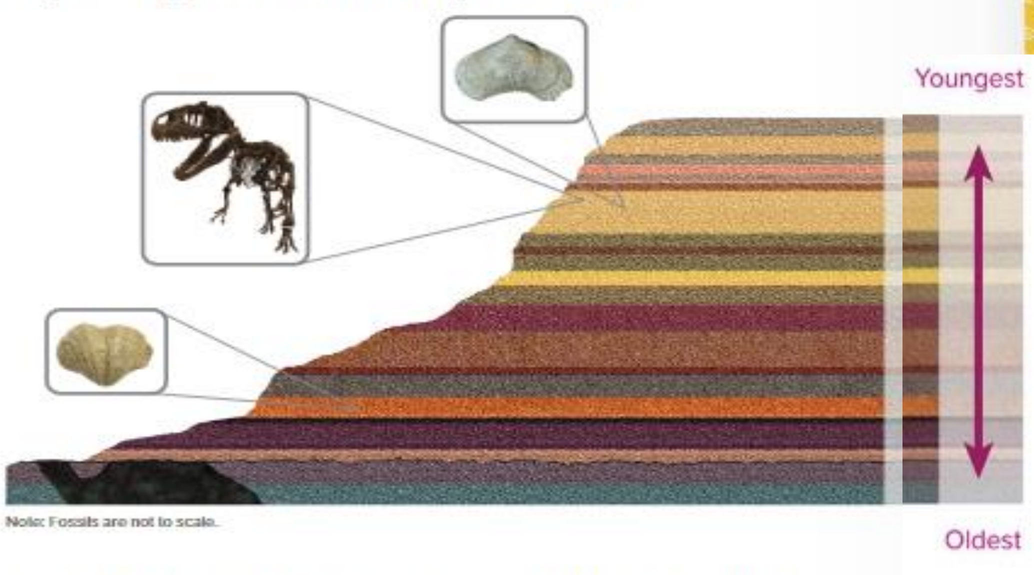
You just discovered how the principles of relative-age dating allow geologists to determine if rocks or features are younger or older than the rocks or features around them. But did you know that the rocks themselves can hold clues about their ages?

LIFE SCIENCE Connection Some of the most obvious clues found in rocks are **fossils**—the remains or traces of ancient living things. How can geologists use fossils to infer the ages of rocks and events in Earth's history? Let's dig in.

INVESTIGATION

Clues to Earth's Past

Analyze the image below. Then answer the questions that follow.



Note: Fossils are not to scale.

1. Using the principle of superposition, determine which rock layers are the oldest, and which rock layers are the youngest. Label the space above and below the arrow heads *Oldest* and *Youngest* accordingly.

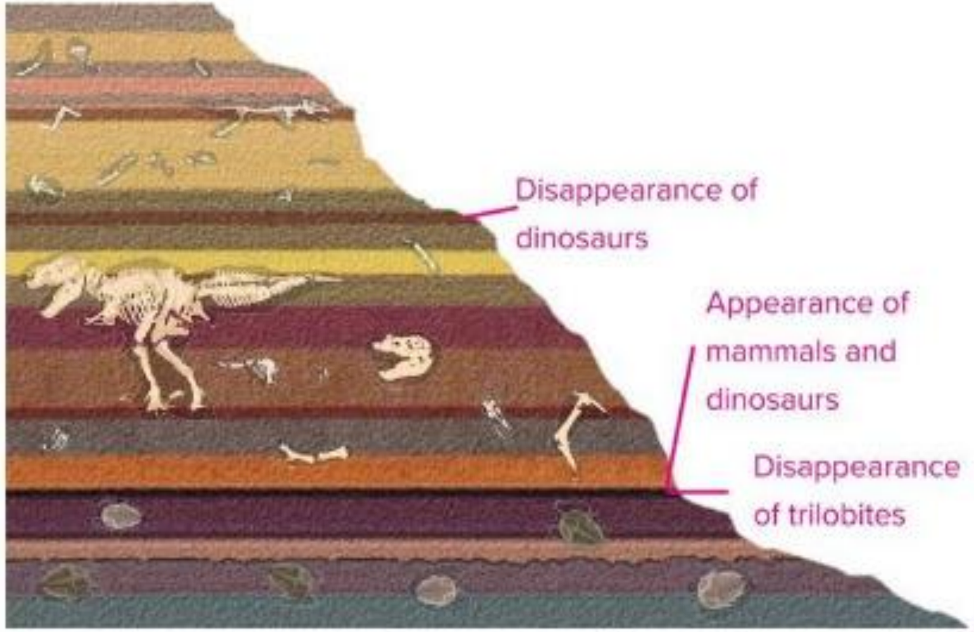
2. Imagine you discovered the fossils in the rock layers on the previous page. What do you notice about the complexity of the fossils in the rocks? Where are the more simple fossils located? Where is the more complex fossil located?

Complex fossils are found in younger rock layers. The more simple fossils are found in both old and young rock layers.

3. Make a claim about how the complexity of fossils in the fossil record can provide clues to the relative ages of rock units.

The fossil record can provide clues based on the complexity of the organisms. Older rock layers only contain simple lifeforms; younger layers contain both simple and complex.

Now, study the image below. Notice the fossil trilobites in the rock layers at the bottom of the sequence. As you move upward in the sequence you'll see fossils of mammals and dinosaurs.



4. When do trilobites disappear from the rock sequence? Label this point *Disappearance of trilobites* in the white space to the right of the image.

5. When do mammals and dinosaurs appear in the rock sequence? Label this point *Appearance of mammals and dinosaurs*.

6. What can you conclude about the layers that contain the trilobites? Are they older or younger than the layers that contain the mammals and dinosaurs?

The rock layers that contain the trilobites are older than the rock layers that contain the mammals and dinosaurs.

7. When do the dinosaurs disappear from the rock sequence? Label this point *Disappearance of dinosaurs* in the white space to the right of the image.

8. What can you conclude about the layers that contain only the mammals? Are they older or younger than the layers that contain the dinosaurs?

The rock layers that contain only mammals are younger than the layers that contain dinosaurs.

9. Make a claim about how the appearance and disappearance of organisms in the fossil record provides relative dates.

Rock layers that contain extinct organisms are older than rock layers that contain fossils of organisms that are still living today.

GO ONLINE for additional opportunities to explore!

LIFE SCIENCE Connection Want to learn more about fossils? Then perform one of the following activities.

- [ ] **Investigate** clues about how organisms lived in the **Lab** *What can trace fossils show?*

OR

- [ ] **Explore** ancient organisms by studying fossil remains in the **Lab** *How is a fossil a clue?*

The Fossil Record While studying the fossils in rock layers, as you just did in the *Clues to Earth's Past* investigation, early geologists recognized three things. First, fossils found in the oldest layers of rock are of relatively simple organisms. Fossils of more complex organisms appear in younger layers of rock. Second, there were a few times when many types of fossils that appear in one rock layer did not appear in the younger rock layers right above it. These sudden disappearances in the fossil record of many types of organisms mark **mass extinctions**—times when many species on Earth died or became extinct within a relatively short period of time.

And finally, fossils and the rocks they are within can be used to determine what the environment of an area was like long ago. Let's look at an example.

INVESTIGATION

Reconstructing Past Environments

GO ONLINE Watch the video *Secrets of the Origin of Life*.

1. What does the earliest evidence of life look like in the fossil record?

The earliest evidence of life is primitive, microbial bacteria.

2. What do these rocks from the video tell scientists about the environment in which they formed?

The rocks suggest that during this time, the location was similar to Iceland today, with volcanic activity creating hot springs.

Ancient Environments Scientists use the principle of uniformitarianism to learn about ancient organisms and the environments where ancient organisms lived. For example, a fossil of an ancient coral is evidence that the surrounding location was a marine environment when the coral was alive.

COLLECT EVIDENCE

How does the fossil record help scientists piece together Earth's history? Record your evidence (B) in the chart at the beginning of the lesson.

Scientists use fossil to piece together earth's history. To determine relative ages, they use the evidence of changing complexities, appearance and disappearance and mass extinctions of fossil organisms.

A Closer Look: Drilling Into the Past

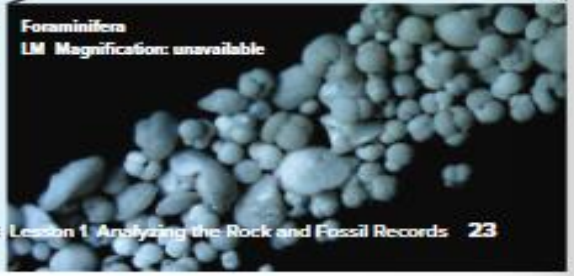
Did you know fossils from the seafloor can provide evidence of past climates? Scientists use core samples of the seafloor to gather data about Earth's history. Each layer holds grains of dust, minerals, and often times pollen, that can provide information about the environment in which they were deposited. Many layers also contain fossils of the organisms that lived in the ocean during that time.

The most common types of fossils analyzed in deep-sea sediment cores are foraminifera. Foraminifera are tiny, unicellular organisms less than the size of a grain of sand. When they grow, foraminifera incorporate oxygen from the surrounding water into their shells.

Oxygen comes in two important varieties for paleoclimate research: heavy (^{18}O) and light (^{16}O). Water vapor molecules containing the heavy isotope condense more readily than water vapor molecules containing the light isotope. When climates are cooler, the water vapor containing ^{18}O rains out of the atmosphere. The wind carries water vapor containing the lighter ^{16}O toward Earth's poles, where it eventually condenses and falls onto the ice sheets where it remains trapped. As a result, the oceans develop increasingly higher concentrations of heavy oxygen during cooler time periods. In general, foraminifera shells contain more heavy oxygen during glacial periods.

It's Your Turn

WRITING Connection Research the latest expeditions of the *JOIDES Resolution*, a scientific drilling ship sponsored by the Joint Oceanographic Institutions for Deep Earth Sampling. Develop a poster showing where the ship has traveled as well as the purpose of its expeditions.



Foraminifera
LM Magnification: unavailable

LESSON 1

Review

Summarize It!

1. **Organize** In the space below, create a graphic organizer summarizing how the relative ages of rocks, geologic features, and events are determined using the rock and fossil records.

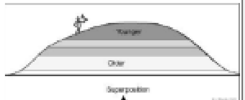
Principles of Relative Dating

The process of placing events in the order that they occurred in the earth.

Superposition

means that

the **oldest rocks** are located on the **BOTTOM** of undisturbed rock layers



OLDEST Rocks

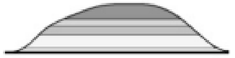
Original Horizontality

means that

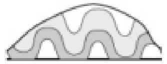
Sedimentary rock layers **always begin** in a **HORIZONTAL POSITION**

Horizon = parallel to the ground

Younger Rock Layers



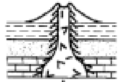
Older Rock Layers

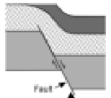


Cross-Cutting Relationship

means that

ANYTHING that **CUTS across rock layers** is **YOUNGER** than the rock layers it cuts through



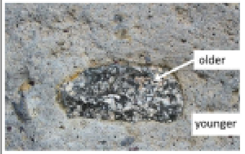


Igneous Intrusions CUT through rock layers and are YOUNGER

FAULTS or CRACKS CUT through rock layers and are YOUNGER

inclusion

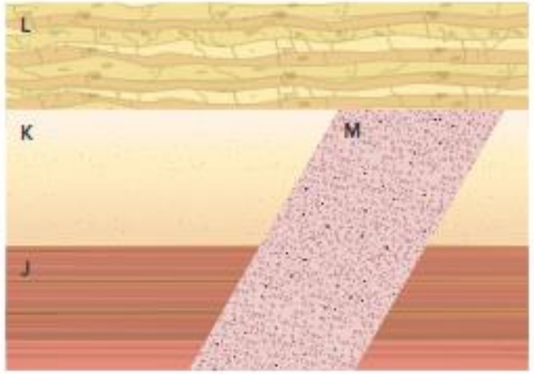
***A piece** of an older rock that becomes **part of** a new rock*



the rock containing the pieces is younger than the pieces

Three-Dimensional Thinking

Imagine you are a geologist. You have been asked to analyze and interpret the rock sequence below. Your task is to determine the relative ages of the rocks.



2. Order the features in the illustration from oldest to youngest.
   - A JKLM
   - B MJKL
   - C JKML
   - D MLKJ

3. Which geologic principle must be assumed to determine the relative age of M?
   - A cross-cutting relationships
   - B superposition
   - C original horizontality
   - D inclusions

Real-World Connection

4. **Contrast** What is your absolute age? What is your relative age compared to two of your classmates? How do these ages contrast?

My absolute age is 13. I am younger than Salvador and older than Cora. Absolute age is a numerical age, whereas relative age is not an exact age, but rather the age of an object, feature, or person in comparison to another.

5. **Predict** Suppose you are a geologist tasked with analyzing the fossil record in your region and determining when a major marine extinction event took place. What changes in the fossil record would you look for?

There would likely be a sudden disappearance of marine fossil organisms in the fossil record. New, different life-forms might appear in the rock layers above the mass extinction event.

Still have questions?
Go online to check your understanding about the rock and fossil records.

REVISIT PAGE KEELEY SCIENCE PROBES

Do you still agree with the answer you chose at the beginning of the lesson? Return to the Science Probe at the beginning of the lesson. Explain why you agree or disagree with that answer now.

EXPLAIN THE PHENOMENON

Revisit your claim about how the sequence of past geologic events can be determined. Review the evidence you collected. Explain how your evidence supports your claim.

START PLANNING

STEM Module Project Science Challenge

Now that you've learned about how geologists analyze the rock and fossil records, go to your Module Project to start planning your video blog. Keep in mind that you want to explain how evidence from rock strata is used to organize Earth's vast geologic past.