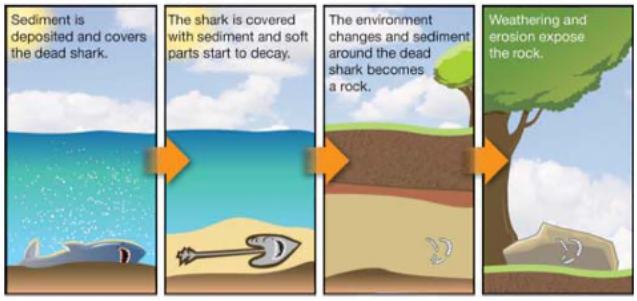
18.2 Relative Dating

Earth science is a large field of science that includes **geology**, the study of the solid matter that constitutes Earth. By "solid matter," we mean rocks. As you read in the chapter introduction, rocks and rock layers contain stories about Earth's history. This section presents some of the scientific processes used to discover and understand these stories.

The beginnings of modern geology

Shark's teeth Nicolas Steno (1638–1686), a Danish anatomist, studied a shark's head and noticed that the shark's teeth resembled mysterious stones called "tongue stones" that were found inside local rocks. At that time, some people believed that tonguestones had either fallen from the moon or that they grew inside the rocks. Steno thought that tongue stones looked like shark's teeth because they *were* shark's teeth that had been buried and became fossils!

How did teeth get inside a rock? Steno realized that when an animal dies it is eventually covered by layers of sediment. The animal's soft parts decay quickly, but bones and teeth do not. Over a long period of time, the sediment around the dead animal becomes rock, with the bones and teeth inside.



VOCABULARY

geology - the study of the solid matter that constitutes Earth.

JOURNAL

The girl in this image is climbing some of the "solid matter" found on Earth. Study the image and answer the following geology questions.

1. How do you think the features of this canyon were made?
2. Which was made first—each layer of rock or the holes and indentations in the rock? Explain your answer.

Relative dating

Steno's ideas Steno's observations helped him develop ideas about how rocks and fossils form. His ideas, which are described on the next page, are still used today in the study of geology as a technique called relative dating. **Relative dating** is the process of putting events in the order in which they happened.

How is relative dating used? Relative dating is used to determine the order of events that affected a rock formation, including the order of its layers. Unlike absolute dating, relative dating does not try to determine the exact age of an object, but instead uses clues to figure out the order of events over time.

Fossils are clues A **fossil** is the remains or traces of a dead animal or plant that has been preserved for a long time. Found within a layer of rock, a fossil can be used to identify the general age of that layer of rock, especially if it is a fossil of a known life form that has been dated using absolute dating. For example, if you found a trilobite fossil within a rock layer, in what era might this layer have been formed? If you said the Paleozoic era, you are correct. A question like this can be answered by a **paleontologist**, a scientist who studies fossils.

The present explains the past Like Steno, Scottish geologist James Hutton (1726–1797) was an important figure in the development of modern geology. Hutton is credited with identifying one of the most important clues for deciphering Earth's history. Hutton realized that if you understand processes that are happening now, you can use that knowledge to explain what happened a long time ago. The short form of his idea is: The present is the key to the past.

The present is the key to the past. —James Hutton

Comparing the present and past You see geologic processes in action on a regular basis. For example, when it rains hard you might see flowing water washing away or eroding sediment (Figure 18.9). When the rain stops, you might observe that grooves were left behind by the flowing water. Observations of common, small-scale events in the present like this are helpful for understanding how large land features formed. For example, the Grand Canyon was eroded by the Colorado River (see the next page).

VOCABULARY

relative dating - the process of putting events in the order in which they happened.

fossil - the remains or traces of a dead animal or plant that has been preserved for a long time.

paleontologist - a scientist who studies and identifies fossils.

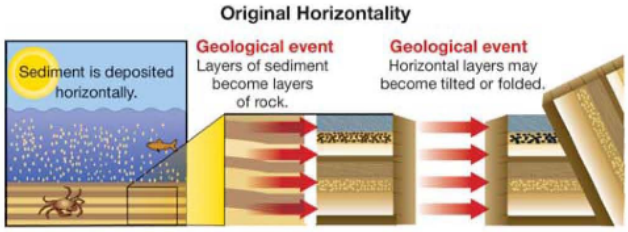
Photo by Jack Dykinga, ARS/USDA.

Figure 18.9: *The way water erodes the land is seen every time it rains.*

Identifying clues using relative dating

Superposition Steno identified the *law of superposition,* which states that the bottom layer of a rock formation is older than the layer on top, because the bottom layer formed first. A stack of newspapers is a good illustration of superposition (Figure 18.10).

Original horizontality Steno also identified the *law of original horizontality* which refers to how sediment particles settle to the bottom of a body of water, such as a lake, in response to gravity. The result is horizontal layers of sediment. Over time, these layers can become layers of rock. As you see in the graphic below, sometimes horizontal layers of rock might become tilted or folded by a geological event, such as an earthquake. Layers might be tilted at any angle and can even be upside down.



Lateral continuity Steno's third contribution to the technique of relative dating and modern geology is the *law of lateral continuity.* Lateral continuity refers to how layers of sediment extend in all directions horizontally. Later, a separation might be caused by a geological event such as erosion (the breaking down of rock as it is moved by water) or movement during an earthquake. The Colorado River created the gap that is now the Grand Canyon. If you were to compare rock layers in the Grand Canyon, you would find that the layers on one side of the canyon match up with the layers on the other side (Figure 18.11).

Figure 18.10: *A stack of newspapers illustrates superposition. The oldest newspaper is on the bottom of the stack and the more recent newspapers are piled on, with the most recent on top.*

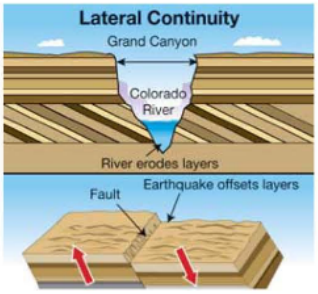
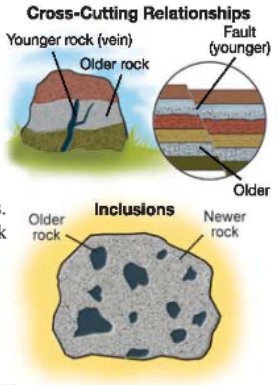


Figure 18.11: *Layers of rock are continuous unless a river erodes the layers or an earthquake moves them.*

Identifying the relative age of a rock or fossil

Cross-cutting relationships

The *principle of cross-cutting relationships* states that a vein of rock or a break (called a fault) that cuts across a rock's layers is younger (more recent) than the layers. The graphic at the right shows a rock formation with three layers and a cross-cutting vein. The rock layers formed first. The vein formed when molten rock oozed into a crack in the original rock, cutting across the layers. The bottom layer is the oldest part of the rock formation and the vein is the youngest. The middle and top layers formed after the bottom layer, but before the vein. Similarly, a fault that cuts across layers of rock will always be younger than the layers.



Inclusions

Sometimes inclusions or pieces of one rock are found inside another rock. During the formation of a rock with inclusions, sediments or melted rock surrounded the inclusions and then solidified. Therefore, the inclusions are older than the surrounding rock. A rock with inclusions is like a chocolate chip cookie. The chocolate chips (inclusions) are made first. Then they are added to the batter (melted rock or sediment) before being baked (hardened) into a cookie (rock).

Fossil succession

The *principle of fossil succession* means that fossils can be used to identify the relative age of the layers of a rock formation. For example, dinosaur fossils are found in rock that is about 200 to 65 million years old because these animals lived that long ago. The fossils of modern human beings (*Homo sapiens*) are only found in rock that is younger than 200,000 years old.

BIOGRAPHY

Hutton, Lyell, and Darwin

A few of the important storytellers of Earth's history are James Hutton (1726–1797), Charles Lyell (1797–1875), and Charles Darwin (1808–1882). Hutton recognized that present events explain how past events occurred, and he understood that the processes that shape Earth take a long time. His ideas were eventually referred to as "uniformitarianism."

Between 1830 and 1833, Lyell published the *Principles of Geology*, a three-volume book that was extremely popular. In his book, Lyell supported uniformitarianism with evidence from his own extensive travels, particularly in North America.

A young Darwin sailed as the ship naturalist on the *HMS Beagle*. On his journey, he found geological and fossil evidence that supported Lyell's ideas in *Principles of Geology* and uniformitarianism. Darwin used his findings to develop his theory of natural selection that said organisms arise from a common ancestor and evolve over a long period of time. His ideas were published in 1859 in *On the Origin of the Species*.

Fossils and Earth's changing surface

One large landmass Fossils provide evidence for how Earth's surface has changed over time. At the beginning of the Mesozoic Era (250 mya), the land on Earth existed as a supercontinent called Pangaea. In the graphic below, find the part of Pangaea that would eventually become South America. How does South America's present day climate compare to what it would have been 250 million years ago?

Earth today Eventually, pieces of Pangaea separated and moved away from the South Pole. The right side of the graphic shows the way land is distributed today. The colors show where you would find the fossils of the organisms featured in Figure 18.12. The black dotted line marks where glaciers used to be.

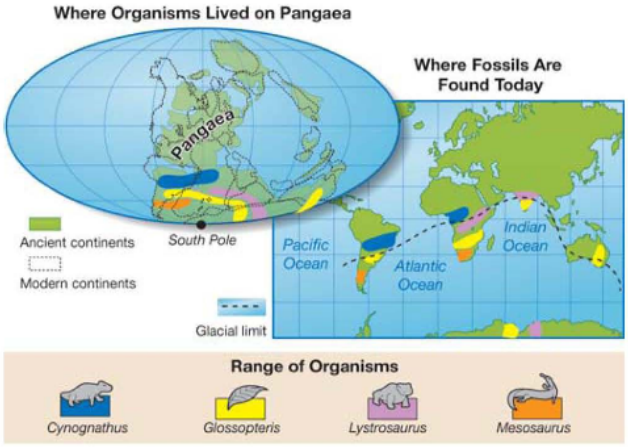
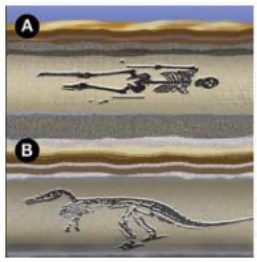


Figure 18.12: *These organisms lived on Earth when the land was connected as one large landmass, Pangaea.*

Section 18.2 Review

1. Describe Nicolas Steno's contribution to modern geology.
2. James Hutton recognized that the present explains the past. Why is this idea so important in modern geology?
3. How are a vein of rock and an inclusion similar? How are they different? Describe a vein and an inclusion in your answer.
4. Use the graphic at the right to answer the following questions. Justify your answers using relative dating principles.
   a. Assuming that the layers are still in the position in which they were laid down, what idea is represented?
   b. Which organism is oldest?
   c. Which is youngest?



5. True or false: Superposition states that rock layers near the surface of Earth are younger than rock layers further from the surface. Explain your reasoning.
6. A geologist sees a series of *vertical* layers of rock. Does this observation disprove the law of original horizontality? Why or why not?
7. Study Figure 18.13 to answer the following questions. Justify your answers using relative dating principles.
   a. Which horizontal layer of rock is the oldest? The youngest?
   b. Which event occurred more recently—H or G?
   c. Are the inclusions in layer B older or younger than layer B?
   d. Form a hypothesis: What is the source of the inclusions in layer B?
   e. List the layers and events in the chronological order in which they occurred.
8. How are layers of rock like a history book?
9. Why is there evidence of glaciers in Africa?
10. Why do some fossils in South America match some fossils in Africa?

CHALLENGE

Use classroom resources, home resources, or the Internet to research the geology of the Grand Canyon. Then, answer the following questions.

When was the Grand Canyon formed?

How was it formed?

What are the different rock layers found in the Grand Canyon?

How old is the oldest rock layer?

How is the Grand Canyon changing today? Why is it changing?

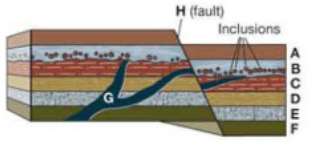


Figure 18.13: *Question 7.*

SCIENCE FACT

Unconformity

In Figure 18.13 you can see that the vein (G) is cut off by a rock layer (B). An interruption like this in the geologic record is called an *unconformity*. How do you think an unconformity forms?