KEY CONCEPT

13.2 Rocks provide a timeline for Earth.

Sunshine State STANDARDS

SC.D.1.3.1: The student knows that mechanical and chemical activities shape and reshape the Earth's land surface by eroding rock and soil in some areas and depositing them in other areas, sometimes in seasonal layers.

SC.D.1.3.2: The student knows that over the whole Earth, organisms are growing, dying, and decaying as new organisms are produced by the old ones.

BEFORE, you learned

- Fossils contain information about the past
- Fossils, ice cores, and tree rings record conditions and changes in the environment

NOW, you will learn

- What the relative ages of rock layers reveal about Earth
- How index fossils are used to determine the ages of rock layers
- How the absolute ages of rocks are determined

THINK ABOUT

How old are these bicycles?

You might not know exactly when each of the bicycles shown was made, but you can probably tell which is the oldest. How could you arrange these bikes in order of their ages without knowing how old each is?

VOCABULARY

relative age p. 465
index fossil p. 467
absolute age p. 469
half-life p. 469

Layers of sedimentary rocks show relative age.

Fossils are clues in the story of Earth's past. But for the story to make sense, the clues need to be arranged in order. **Relative age** is the age of an event or object in relation to other events or objects. You probably know relative ages for many things in your life. For example, if a friend tells you she has an older brother and a younger brother, you know the relative ages of her brothers even if you don't know their exact ages.

Until the beginning of the 1900s, geologists didn't have a way to determine the exact ages of objects that existed in Earth's past. Instead, they reconstructed Earth's story based on the relative ages of different clues. Today there are still many parts of Earth's history that cannot be given exact ages. Determining relative age continues to be an important way of piecing together the puzzle of Earth's past.

VOCABULARY
Add a description wheel for *relative age* to your notebook.

READING TiP

- *Vertical* means "straight up and down."

vertical

- *Horizontal* means "level."

horizontal

Sedimentary rock layers contain information about the relative ages of events and objects in Earth's history. As you read earlier, sedimentary rocks form from the sediments that fall to the bottom of lakes, rivers, and seas. Over time, the sediments pile up to form horizontal layers of sedimentary rocks. The bottom layer of rock forms first, which means it is oldest. Each layer above that is younger, and the top layer is youngest of all. This ordering is relative because you cannot be sure exactly when each layer formed, only that each layer is younger then the one below it.

When horizontal layers of sedimentary rock are undisturbed, the youngest layer is always on top, as shown in the photograph on the left below. But over millions of years, the movement of tectonic plates can disturb rock layers. A whole set of layers can get turned on its side. Rock layers can get bent, or even folded over, like taco shells that begin as flat tortillas. If a set of rock layers has been disturbed, the youngest layer may no longer be on top. One way scientists determine the original order is to compare the disturbed rock layers with a similar but undisturbed stack of layers.

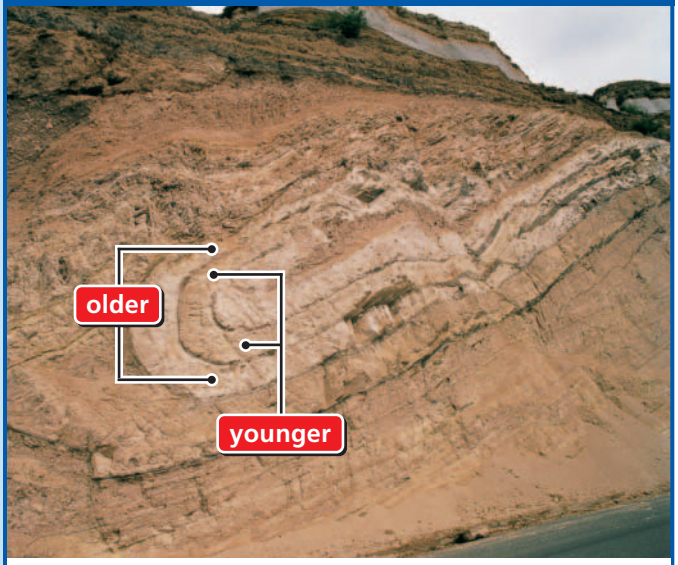
CHECK YOUR READING When might the youngest layer in a set of sedimentary rock layers not be on top?

Rock Layers

Undisturbed Layers

Because sedimentary rock forms in layers, the oldest layer of undisturbed sedimentary rock will be on the bottom and the youngest on top.

Disturbed Layers



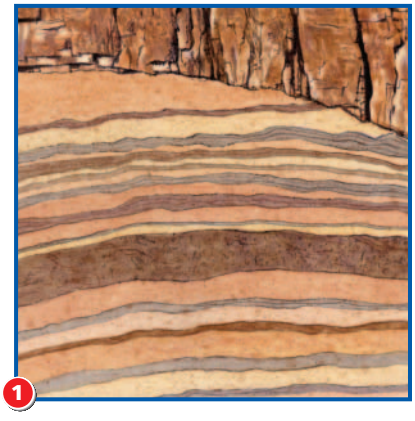
If the rock layers are bent, they may no longer be in order from oldest to youngest.

READING VISUALS Where are the youngest layers in each photo?

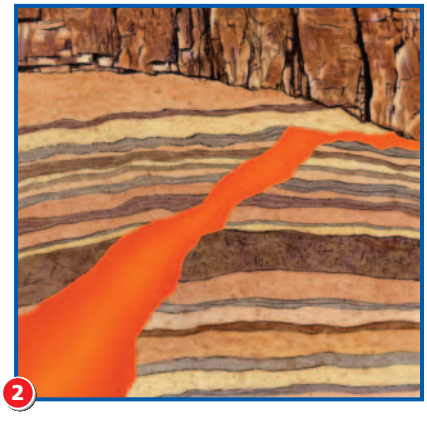
Igneous Rock and Sedimentary Layers

Sedimentary rock layers can also be disturbed by igneous rock. Molten rock from within Earth can force its way up through the layers above it, cooling and forming igneous rock. Because the sedimentary rock layers have to be present before the molten rock cuts through them, the igneous rock must be younger than the layers it cuts through.

VISUALIZATION
CLASSZONE.COM
Watch molten rock cut through layers of sedimentary rock.



Over time, sand and silt form horizontal layers of sedimentary rock.



Deep underground, molten rock cuts through the sedimentary rock layers.

A river gradually wears away the rock, exposing the younger igneous rock.

If the molten rock erupts and flows onto the surface, it forms a layer of igneous rock on top of the layers of sedimentary rock. Over time, more sedimentary rock layers may form on top of the igneous rock. The igneous rock layer is younger than the sedimentary layers under it and older than the sedimentary layers that form on top of it.

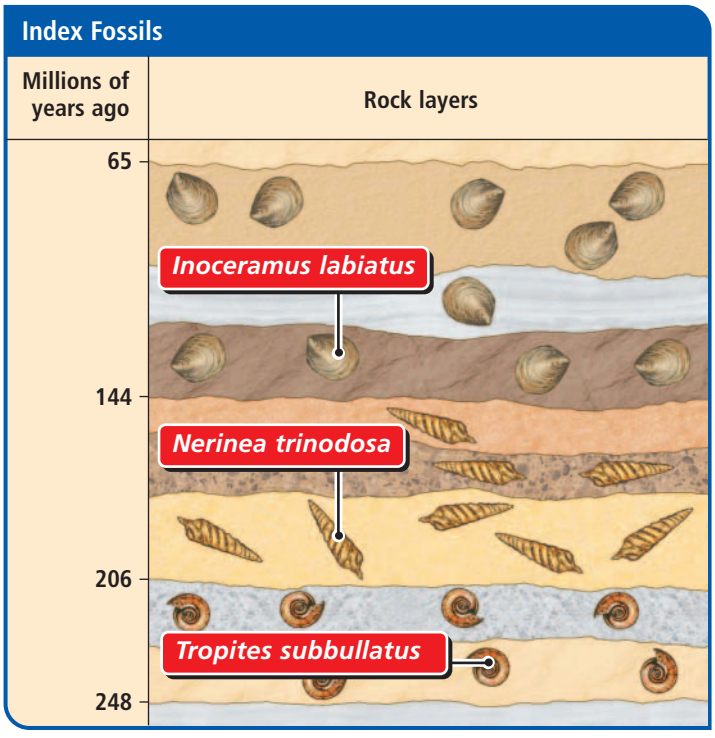
CHECK YOUR READING Why is igneous rock always younger than any rock it cuts through?

Index Fossils

Fossils contained within sedimentary rock can offer clues about the age of the rock. An organism that was fossilized in rock must have lived during the same time span in which the rock formed. Using information from rocks and other natural evidence, scientists have determined when specific fossilized organisms existed. If people know how long ago a fossilized organism lived, then they can figure out the age of the rock in which the fossil was found.

Fossils of organisms that were common, that lived in many areas, and that existed only during specific spans of time are called **index fossils.** These characteristics of index fossils make them especially useful for figuring out when rock layers formed.

This rock contains the index fossil *Arnioceras semicostatum,* an organism that lived between 206 million and 144 million years ago.



Index fossils can be used to estimate the ages of the rocks in which they are found.

The mollusk *Inoceramus labiatus*, for example, is a kind of sea animal that appeared 144 million years ago and went extinct 65 million years ago. So, if you find a rock that contains a fossil of this mollusk, the rock must be between 144 million and 65 million years old because this mollusk lived during that time span.

The chart shows a cross section of rock layers in which *Inoceramus labiatus* and two other index fossils are found. *Nerinea trinodosa* is a kind of sea animal that lived between 206 million and 144 million years ago. *Tropites subbullatus* is a kind of sea animal that lived between 248 million and 206 million years ago.

Remember that one characteristic of index fossils is that they are widespread—they are found in many different parts of the world. Because they are widespread, index fossils can be used to compare the ages of rock layers in different parts of the world.

INVESTIGATE Relative and Absolute Age

How can newspapers model rock layers?

SKILL FOCUS
Making models

MATERIALS
- 5 or more newspapers with different dates
- 2 pencils

TIME
20 minutes

PROCEDURE

1. Have one person in your group arrange the newspapers in a pile with the oldest newspaper on the bottom and the newest on top.
2. After the newspapers are stacked, place one pencil between two newspapers and the other pencil between two different newspapers. Use the model to answer the questions below.

WHAT DO YOU THINK?

- If the newspapers were really placed on the stack on the days they were published, which pencil has probably been there longer?
- Look at the dates on the newspapers. Now what can you say about when the pencils were placed on the stack?

CHALLENGE How does what you could tell about the "ages" of the pencils before looking at the dates differ from what you could tell after looking?

Radioactive dating can show absolute age.

Think again about the friend who tells you that she has two brothers, one older than she is and one younger. You know the order in which they were born—that is, their relative ages. The older brother, however, might be 1 year older or 20 years older. The exact age of the younger brother is also still a mystery. To find out how much older or younger your friend's brothers are, you need to know their actual ages. The actual age of an event or object is called its **absolute age.**

CHECK YOUR READING What is the difference between relative age and absolute age? Use an example in your explanation.

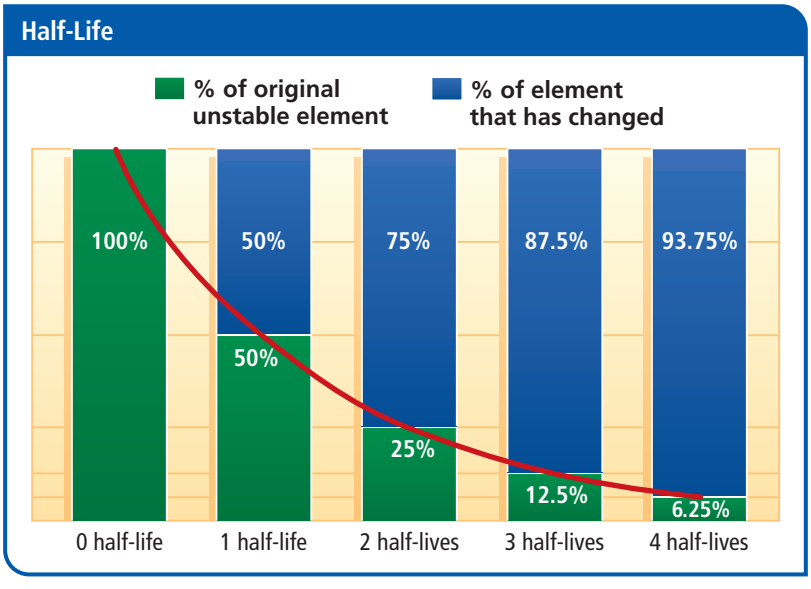
Half-Life

Because scientists can't ask a rock its age, they have had to find a different way of determining the absolute ages of rocks. The solution lies in the smallest unit of matter, the atom. Atoms make up everything on Earth, including you and rocks. The atoms of many chemical elements exist in various forms. Some of these forms are unstable and break down over time into another form. This breakdown—called radioactivity—is a very useful clock because a particular unstable form of an element always breaks down at the same rate into the same other form.

The rate of change of a radioactive element is measured in half-lives. A **half-life** is the length of time it takes for half of the atoms in a sample of a radioactive element to change from an unstable form into another form. Different elements have different half-lives, ranging from fractions of a second to billions of years.

Just as a ruler is not a very useful tool for measuring the distance between planets, elements with very short half-lives are not very useful for measuring the ages of rocks. Instead, elements with half-lives of millions to billions of years are used to date rocks. For example, uranium 235 has a half-life of 704 million years. Uranium 235 is an unstable element found in some igneous rocks. Over time, uranium 235 breaks down into lead 207. Using information from radioactive dating of rocks, scientists estimate that Earth is around 4.6 billion years old.

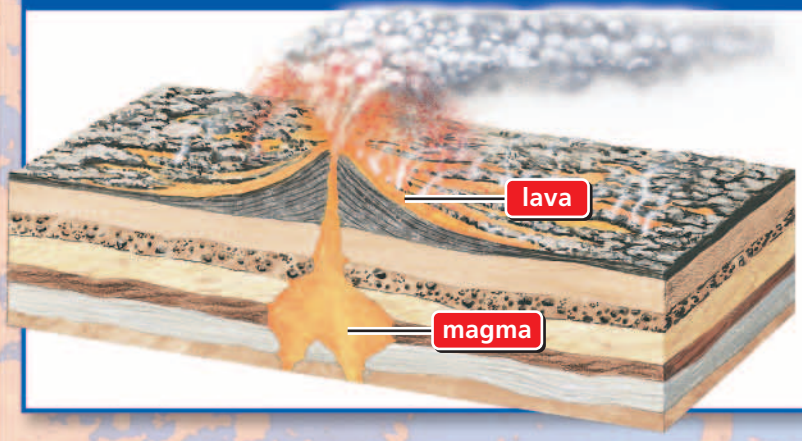
Over time, a radioactive element breaks down at a constant rate into another form.

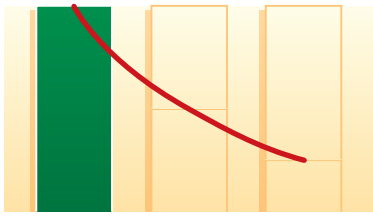


Radioactive Breakdown and Dating Rock Layers

Igneous rocks contain radioactive elements that break down over time. This breakdown can be used to tell the ages of the rocks.

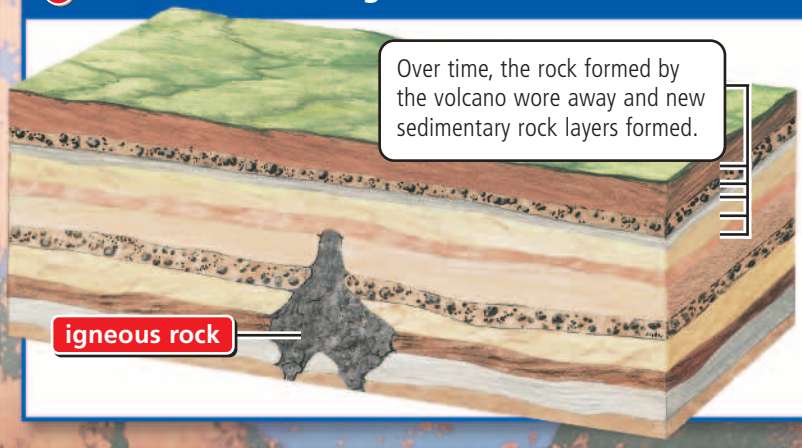
1 1408 Million Years Ago

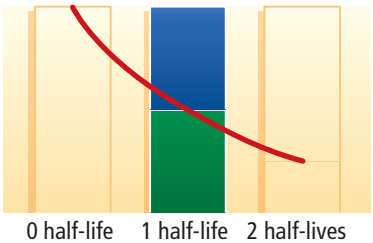




When magma first hardens into rock, it contains some uranium 235 and no lead 207.

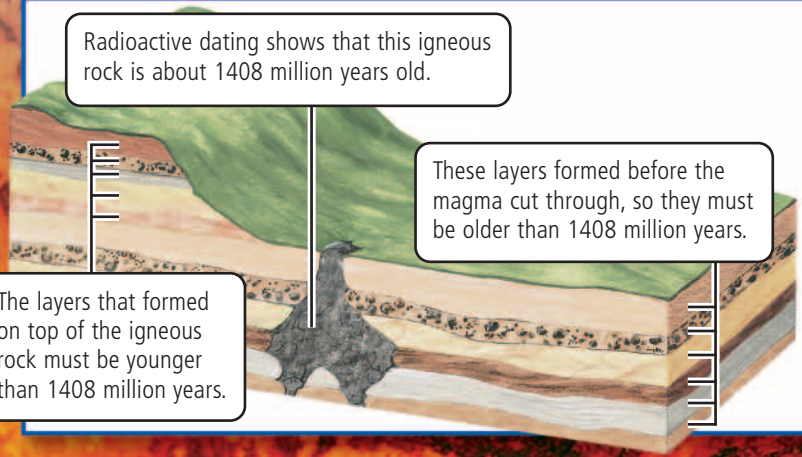
2 704 Million Years Ago

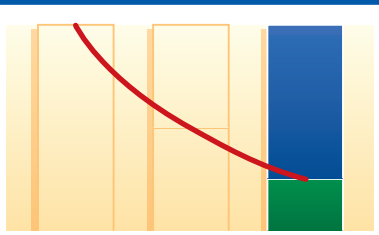




After 704 million years, or one half-life, half of the uranium 235 in the igneous rock has broken down into lead 207.

3 Today





After 1408 million years, or 2 half-lives, only one-fourth of the uranium 235 in the igneous rock remains.

READING VISUALS How do the relative amounts of uranium 235 and lead 207 in the igneous rock change over time?

Radioactive dating works best with igneous rocks. Sedimentary rocks are formed from material that came from other rocks. For this reason, any measurements would show when the original rocks were formed, not when the sedimentary rock itself formed.

Just as uranium 235 can be used to date igneous rocks, carbon 14 can be used to find the ages of the remains of some things that were once alive. Carbon 14 is an unstable form of carbon, an element found in all living things. Carbon 14 has a half-life of 5730 years. It is useful for dating objects between about 100 and 70,000 years old, such as the wood from an ancient tool or the remains of an animal from the Ice Age.

RESOURCE CENTER
CLASSZONE.COM
Find out more about how scientists date rocks.

Using Absolute and Relative Age

Scientists must piece together information from all methods of determining age to figure out the story of Earth's past.

- Radioactive dating of igneous rocks reveals their absolute age.
- Interpreting layers of sedimentary rock shows the relative order of events.
- Fossils help to sort out the sedimentary record.

You have read that it is not possible to date sedimentary rocks with radioactivity directly. Geologists, however, can date any igneous rock that might have cut through or formed a layer between sedimentary layers. Then, using the absolute age of the igneous rock, geologists can estimate the ages of nearby sedimentary layers.

CHECK YOUR READING How might the absolute age of an igneous rock layer help scientists to determine the ages of nearby sedimentary rock layers?

13.2 Review

KEY CONCEPTS

1. What can you tell from undisturbed rock layers? Discuss the concept of relative age in your answer.
2. How can index fossils help scientists determine the ages of rock layers?
3. What property of radioactive elements makes them useful for determining absolute age?

CRITICAL THINKING

4. **Provide Examples** What are some things in your life for which you know only their relative ages?
5. **Apply** In your daily life are there index events (like index fossils) that tell you approximate times even when you can't see a clock? What are they?

CHALLENGE

6. **Apply** A rock contains a radioactive element with a half-life of 100 million years. Tests show that the element in the rock has gone through three half-lives. How old is the rock?