Section 1

Earth's Story and Those Who First Listened

Terms to Learn

uniformitarianism
catastrophism

What You'll Do

- Identify the role of uniformitarianism in Earth science.
- Contrast uniformitarianism with catastrophism.
- Describe how the role of catastrophism in Earth science has changed.

Humans have wondered about Earth's history for thousands of years. But the branch of Earth science called *geology,* which involves the study of Earth's history, got a late start. The main concept of modern geology was not outlined until the late eighteenth century. Within a few decades, this concept replaced a more traditional concept of Earth's history. Today, both concepts are an essential part of Earth science.

The Principle of Uniformitarianism

In 1795, a philosopher and scientist named James Hutton published *Theory of the Earth,* in which he wrote that Earth's landforms are constantly changing. As shown in **Figure 1,** Hutton assumed that these changes result from geologic processes—such as the breakdown of rock and the transport of sediment—that remain uniform, or do not change, over time. This assumption is now called uniformitarianism. **Uniformitarianism** is a principle that states that the same geologic processes shaping the Earth today have been at work throughout Earth's history. "The present is the key to the past" is a phrase that best summarizes uniformitarianism.

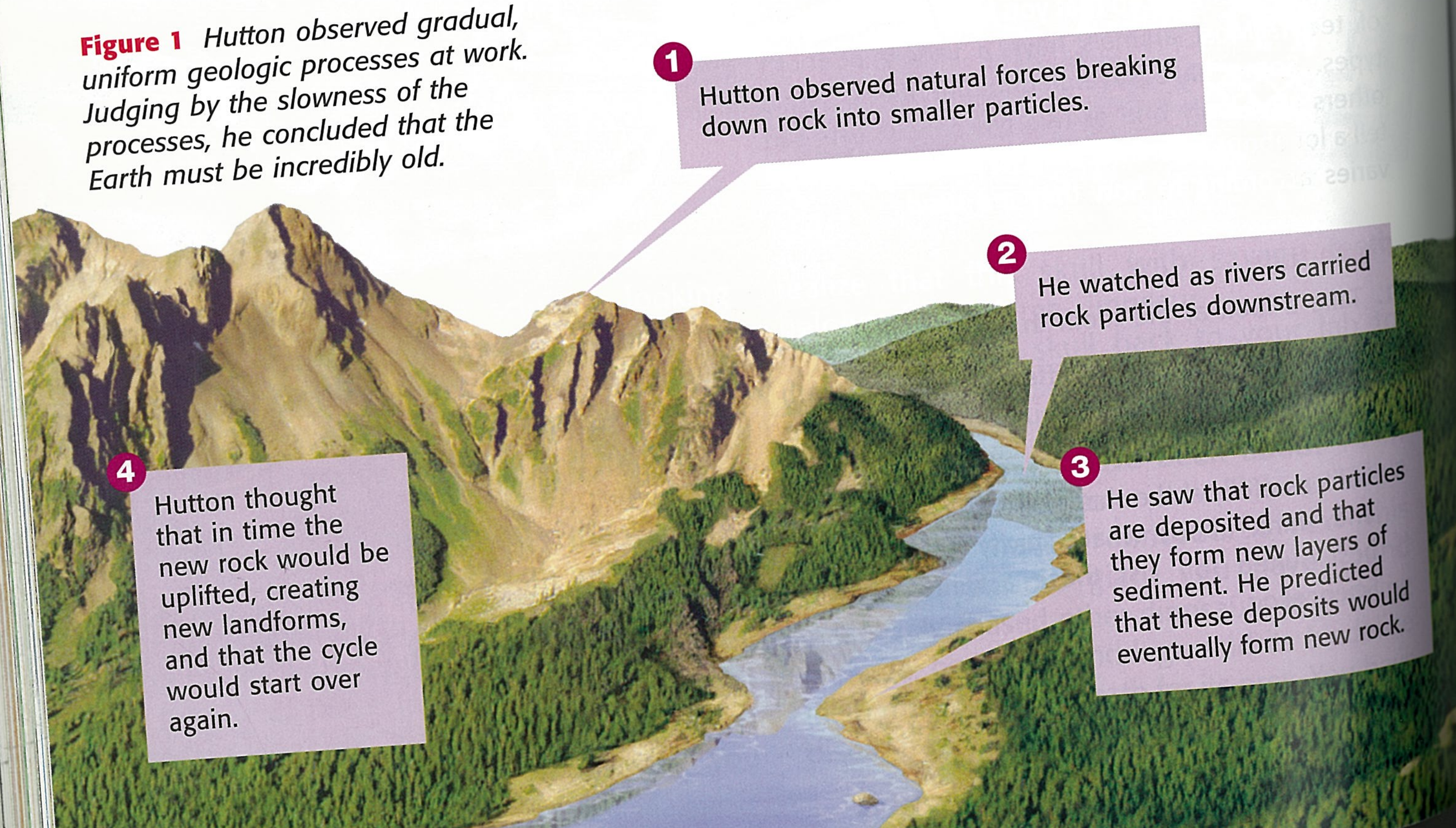


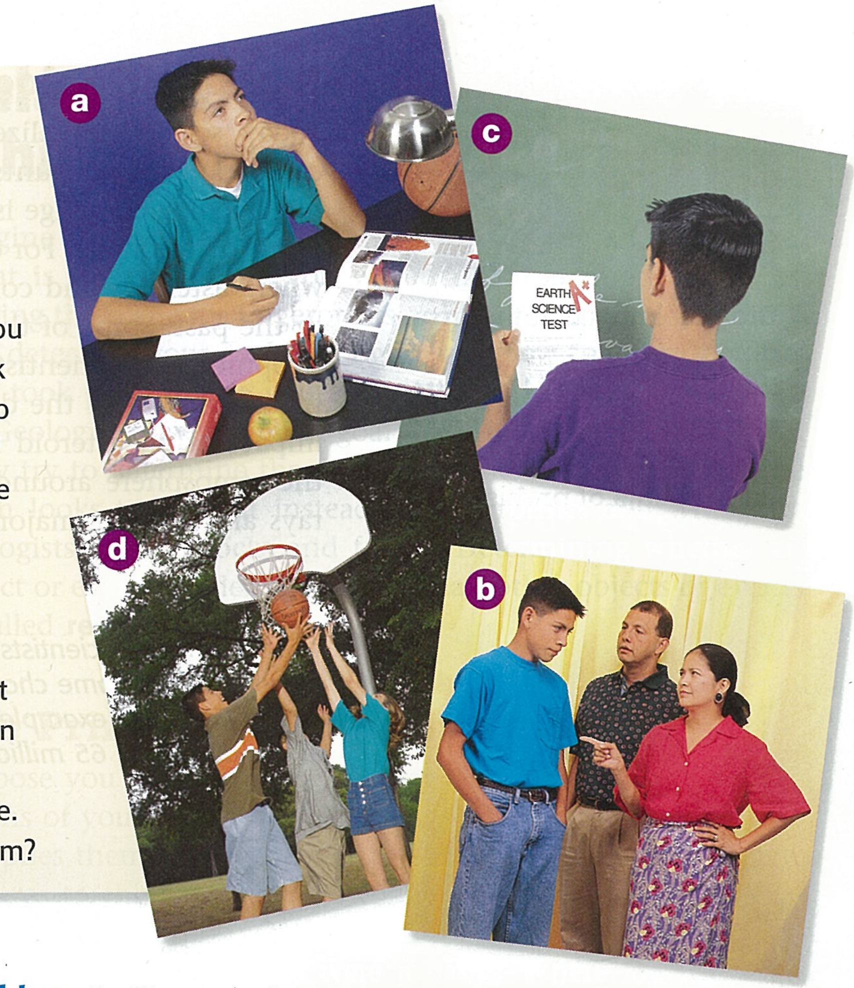
Figure 1 *Hutton observed gradual, uniform geologic processes at work. Judging by the slowness of the processes, he concluded that the Earth must be incredibly old.*

APPLY

Making Assumptions

Examine the photographs at right. List the letters of the photos in the order you think the photos were taken. Now think of all the assumptions that you made to infer that order. Write down as many of these assumptions as you can. Compare notes with your classmates. Did you get the same sequence? Were your assumptions similar?

In science, assumptions must also be made. For example, you assume that the sun will rise each day. Briefly explain the importance of being able to count on certain things always being the same. How does this apply to uniformitarianism?



Uniformitarianism Versus Catastrophism In Hutton's time most people thought that the Earth had existed for only thousands of years. This was not nearly enough time for the gradual geologic processes that Hutton described to have shaped our planet. But uniformitarianism was not immediately accepted. Instead, most scientists believed in catastrophism. **Catastrophism** is a principle that states that all geologic change occurs suddenly. Supporters of catastrophism claimed that the formation of all Earth's features, such as its mountains, canyons, and seas, could be explained by rare, sudden events called *catastrophes.* These unpredictable catastrophes caused rapid geologic changes over large areas—sometimes even globally.

Uniformitarianism Wins! Despite Hutton's observations, catastrophism remained geology's guiding principle for decades. It took the work of Charles Lyell, another scientist, for people to seriously consider uniformitarianism.

From 1830 to 1833, Lyell published three volumes collectively titled *Principles of Geology,* in which he reintroduced uniformitarianism. Armed with Hutton's notes and new evidence of his own, Lyell successfully challenged the principle of catastrophism. Lyell saw no reason to doubt that major geologic change happened the same way in the past as it does in the present—gradually.

Biology CONNECTION

As a friend of Charles Lyell, Charles Darwin was greatly influenced by Lyell's uniformitarian ideas. Lyell's influence became clear when Darwin published *On the Origin of Species by Natural Selection* in 1859. Similar to uniformitarianism, Darwin's theory of evolution proposes that changes in species occur gradually over long periods of time.

Modern Geology—A Happy Medium

Today scientists realize that neither uniformitarianism nor catastrophism accounts for all of Earth's history. Although most geologic change is gradual and uniform, catastrophes do occur occasionally. For example, huge craters have been found where asteroids and comets are thought to have struck Earth in the past. Some of these strikes indeed may have been catastrophic. Some scientists think one such asteroid strike led to the extinction of the dinosaurs, as explained in **Figure 2.** The impact of an asteroid is thought to have spread debris into the atmosphere around the entire planet, blocking the sun's rays and causing major changes in the global climate.

BRAIN FOOD

Did you know that the first dinosaur bones were not identified until 1841? Hutton and Lyell developed their ideas without knowledge of these giants of prehistory.

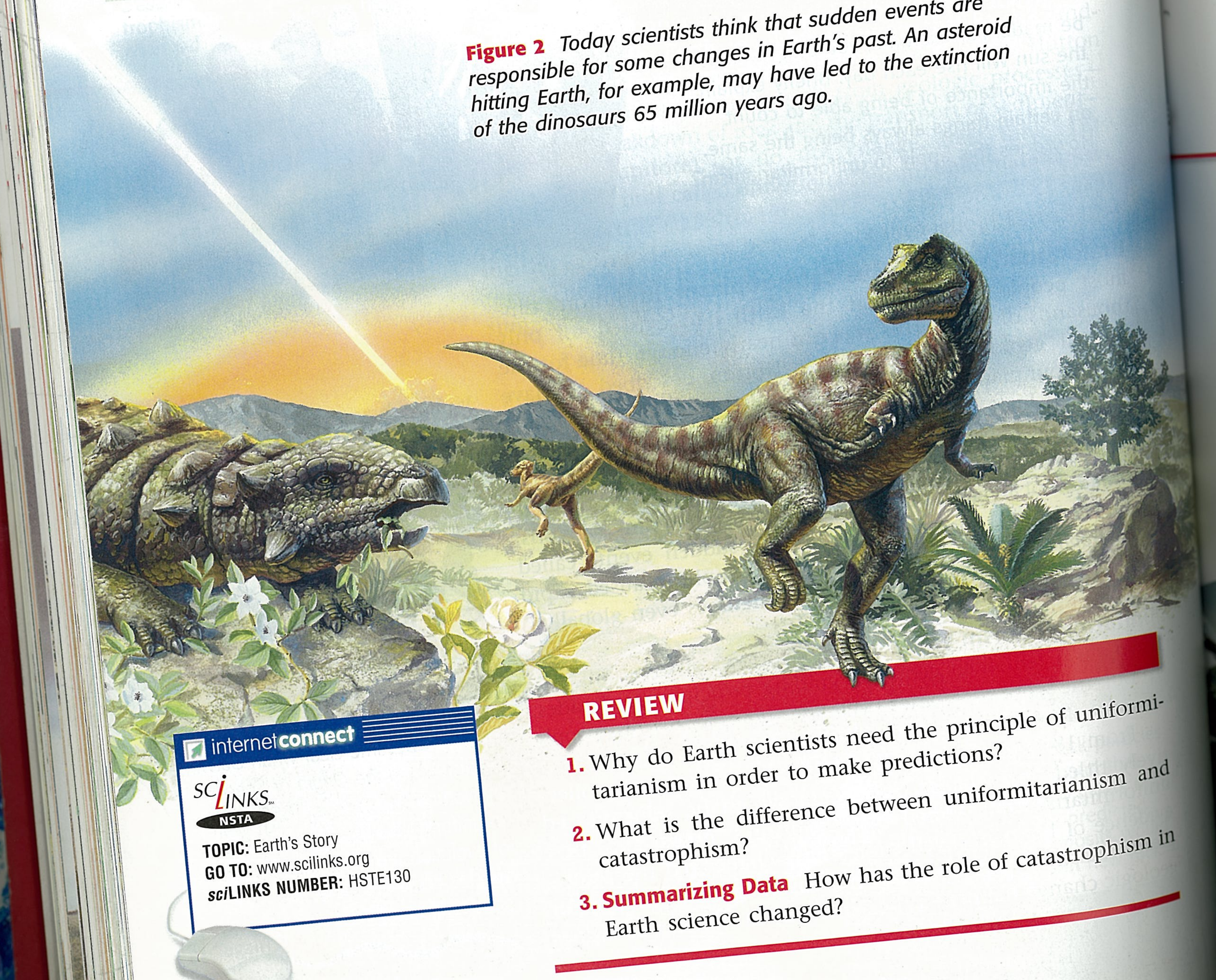


Figure 2 *Today scientists think that sudden events are responsible for some changes in Earth's past. An asteroid hitting Earth, for example, may have led to the extinction of the dinosaurs 65 million years ago.*

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REVIEW

1. Why do Earth scientists need the principle of uniformitarianism in order to make predictions?
2. What is the difference between uniformitarianism and catastrophism?
3. **Summarizing Data** How has the role of catastrophism in Earth science changed?

Section 2

Relative Dating: Which Came First?

Terms to Learn

relative dating
superposition
geologic column
unconformity

What You'll Do

- Explain how relative dating is used in geology.
- Explain the principle of superposition.
- Demonstrate an understanding of the geologic column.
- Identify two events and two features that disrupt rock sequences.
- Explain how physical features are used to determine relative ages.

Imagine that you are a detective investigating a crime scene. What is the first thing you would do? You might begin by dusting the scene for fingerprints or by searching for witnesses. As a detective, your goal is to figure out the sequence of events that took place before you arrived at the scene.

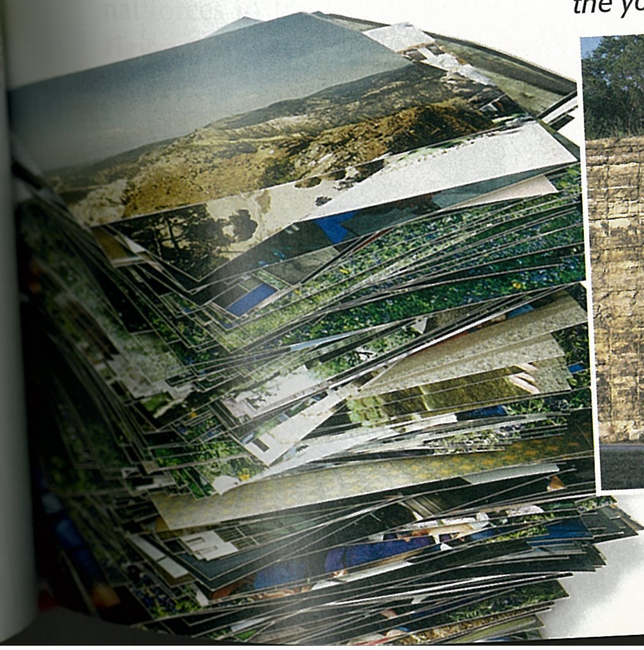
Geologists have a similar goal when investigating the Earth. They try to determine the order of events that led to how the Earth looks today. But instead of fingerprints and witnesses, geologists rely on rocks and fossils. Determining whether an object or event is older or younger than other objects or events is called **relative dating.**

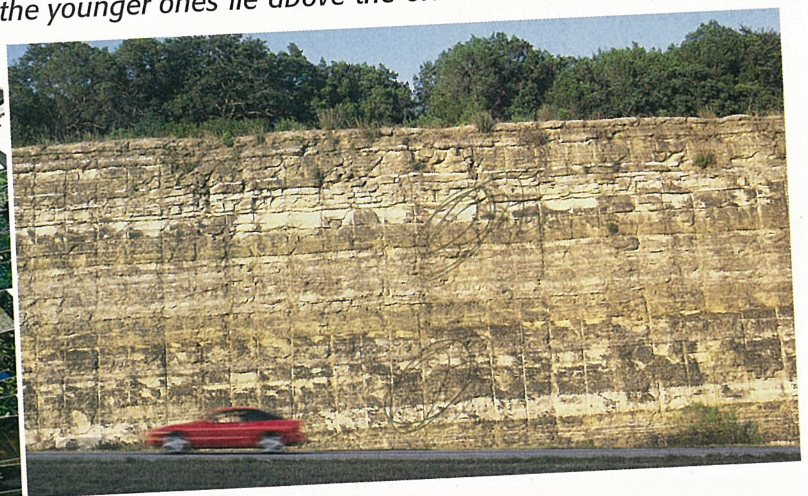
The Principle of Superposition

Suppose you have an older brother who takes a lot of photographs of your family but never puts them into an album. He just piles them in a box. Over the years, he keeps adding new pictures to the top of the stack. Think about the family history recorded in those pictures. Where are the oldest pictures—the ones taken when you were a baby? Where are the most recent pictures—those taken last week?

Rock layers, such as the ones shown in **Figure 3,** are like stacked pictures. The oldest layers are at the bottom. As you move from bottom to top, the layers get more recent, or younger. Scientists call this superposition. **Superposition** is a principle that states that younger rocks lie above older rocks in undisturbed sequences. "Younger over older" is a phrase you can use to remember this principle.

Figure 3 *Rock layers are like photos stacked over time—the younger ones lie above the older ones.*





Activity

1. Write the titles of 10 chapters of this book on 10 note cards (one title on each note card).
2. Shuffle the cards and exchange them with a partner. Try to put your partner's titles in the correct order without using your book.
3. Compare your order with the order in the book.
4. Your work would have been easier if you had been allowed to use your book. How does this relate to geologists using the geologic column to put rock layers in order?

Disturbing Forces Some rock-layer sequences, however, are disturbed by forces from within the Earth. These forces can push other rocks into a sequence, tilt or fold rock layers, and break sequences into movable parts. Sometimes these forces even put older layers above younger layers, which goes against superposition. The disruptions of rock sequences caused by these forces pose a great challenge to geologists trying to determine the relative ages of rocks. Fortunately, geologists can get help from a very valuable tool—the geologic column.

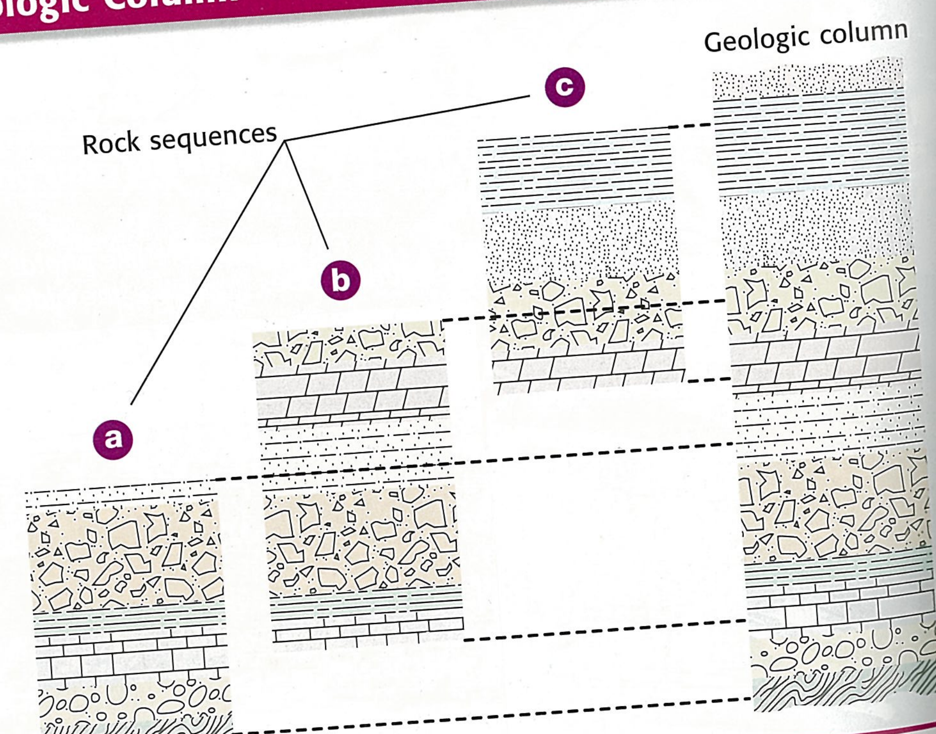
The Geologic Column

To make their job easier, geologists combine data from all the known undisturbed rock sequences around the world. From this information, geologists create the *geologic column*. The **geologic column** is an ideal sequence of rock layers that contains all the known fossils and rock formations on Earth arranged from oldest to youngest.

Geologists rely on the geologic column to interpret rock sequences. For example, when geologists are not sure about the age of a rock sequence they are studying, they gather information about the sequence and compare it to the geologic column. Geologists also use the geologic column to identify the layers in puzzling rock sequences, such as sequences that have been folded over.

Constructing the Geologic Column

Here you can see three rock sequences (**a, b,** and **c**) from three different locations. Some rock layers appear in more than one sequence. Geologists construct the geologic column by piecing together different rock sequences from all over the world.



Disturbed Rock Layers

Geologists often find features that cut through existing rock layers. Geologists use the relationships between rock layers and the features that cut across them to assign relative ages to the features and the layers. They know that those features are younger than the rock layers because the rock layers had to be present before the features could cut across them.

Faults and intrusions are examples of features that cut across rock layers. A *fault* is a break in the Earth's crust along which blocks of the crust slide relative to one another. Another cross-cutting feature is an intrusion. An *intrusion* is molten rock from the Earth's interior that squeezes into existing rock and cools. **Figure 4** illustrates both of these features.

LabBook
Turn to page 652 in the LabBook to learn how geologists construct the geologic column.

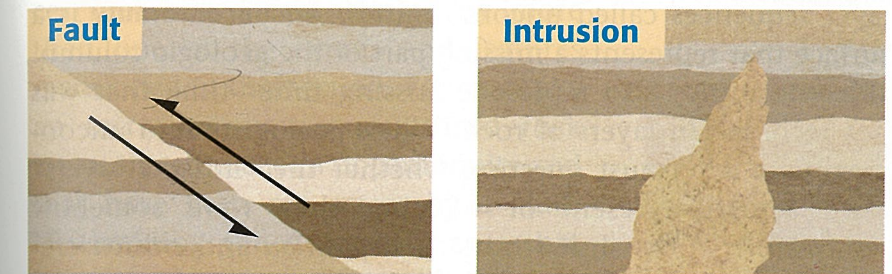


Figure 4 *A fault (left) and an intrusion (right) are always younger than the layers they cut across.*

Geologists assume that the way sediment is deposited to form rock layers—in horizontal layers—has not changed over time. According to this principle, if rock layers are not horizontal, something must have disturbed them after they formed. This principle allows geologists to determine the relative ages of rock layers and the events that disturbed them.

Folding and tilting are two additional types of events that disturb rock layers. *Folding* occurs when rock layers bend and buckle from Earth's internal forces. *Tilting* occurs when internal forces in the Earth slant rock layers without folding them. **Figure 5** illustrates the results of folding and tilting.

Figure 5 *Folding (left) and tilting (right) are events that are always younger than the rock layers they affect.*

Gaps in the Record—Unconformities

Faults, intrusions, and the effects of folding and tilting can make dating rock layers a challenge. But sometimes layers of rock are missing altogether, creating a gap in the geologic record. To think of this another way, let's say that you stack your newspapers every day after reading them. Now let's suppose you want to look at a paper you read 10 days ago. You know that the paper you want should be 10 papers deep in the stack. But when you look, the paper is not there. What happened? Perhaps you forgot to put the paper in the stack. Now instead of a missing newspaper, imagine a missing rock layer.

BRAIN FOOD

Many high-rise apartment and office buildings exhibit something similar to an unconformity—they do not have a 13th floor. Instead, the floors skip from 12 to 14.

Missing Evidence Missing rock layers create gaps in rock-layer sequences called unconformities. An **unconformity** is a surface that represents a missing part of the geologic column. Unconformities also represent missing time—time that was not recorded in layers of rock. When geologists find unconformities, they must question whether the "missing layers" were actually present or whether they were somehow removed. **Figure 6** shows how *nondeposition* and *erosion* create unconformities.

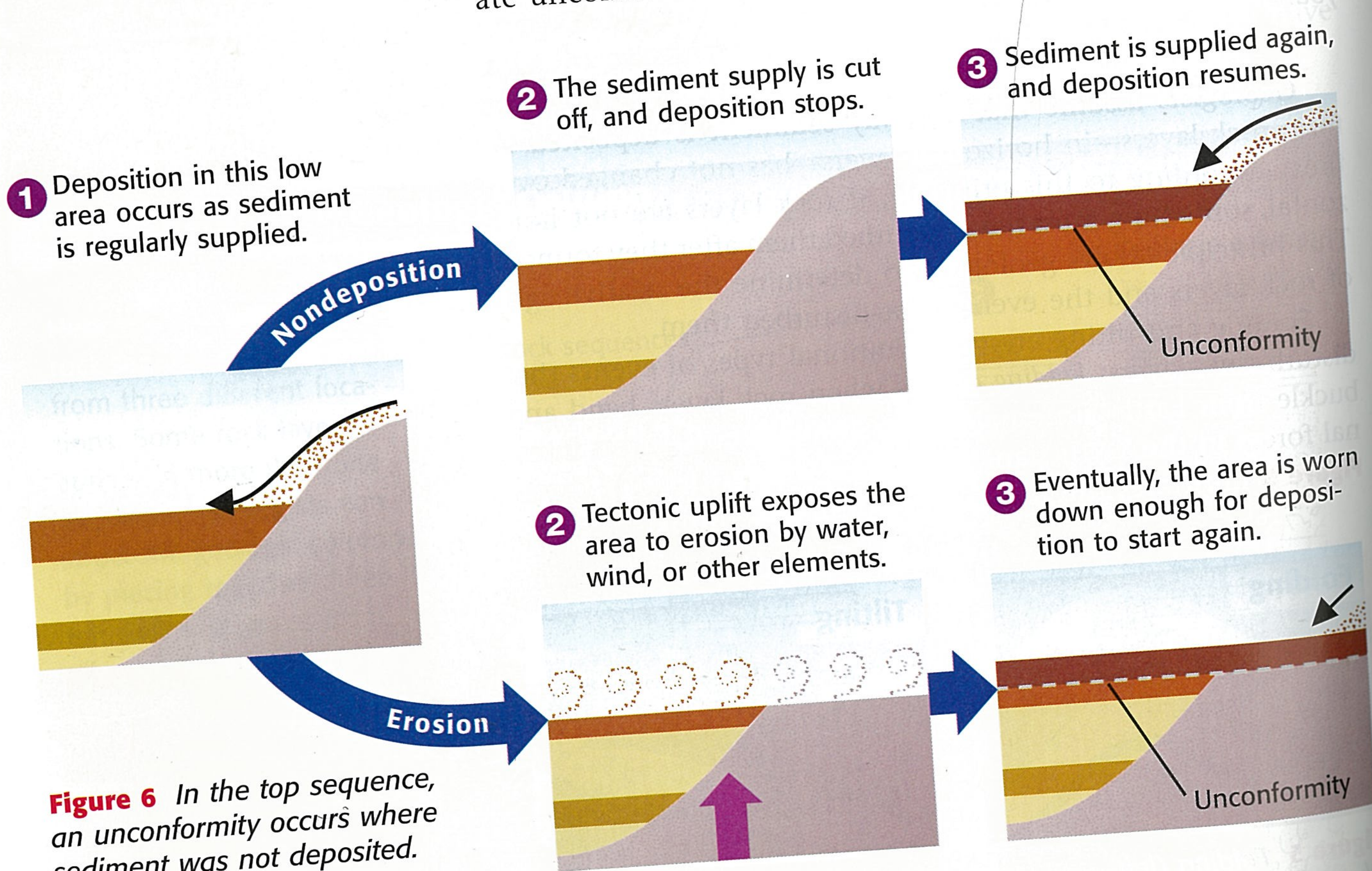


Figure 6 *In the top sequence, an unconformity occurs where sediment was not deposited. In the lower sequence, an unconformity occurs where a rock layer was eroded.*

Types of Unconformities

Most unconformities form by both erosion and nondeposition. But other factors can complicate matters. To simplify the study of unconformities, geologists put them in three major categories—disconformities, nonconformities, and angular unconformities. The three diagrams at right illustrate these three categories.

Rock-Layer Puzzles

Geologists often find rock-layer sequences that have been affected by more than one of the events and features mentioned in this section. For example, an intrusion may squeeze into rock layers that contain an unconformity and that have been cut across by a fault. Determining the order of events that led to such a sequence is like piecing together a jigsaw puzzle.

REVIEW

1. In a rock-layer sequence that hasn't been disturbed, are older layers found on top of younger layers? What rule do you use to answer this question?
2. List five events or features that can disturb rock-layer sequences.
3. Consider a fault that cuts through all the layers of a rock-layer sequence. Is the fault older or younger than the layers? Explain.
4. **Analyzing Methods** Unlike other types of unconformities, disconformities are hard to recognize because all the layers are horizontal. How does a geologist know when he or she is looking at a disconformity?

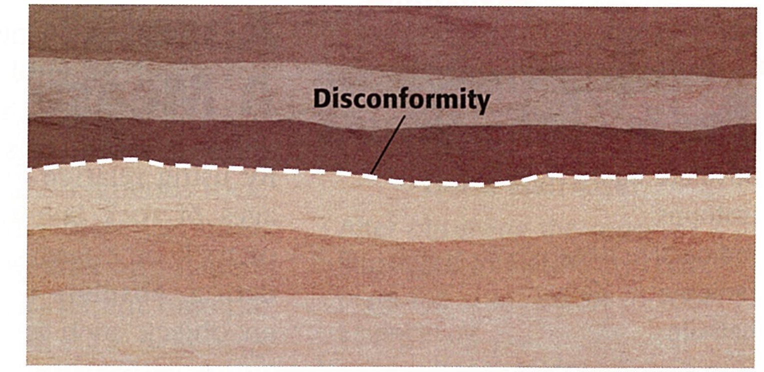


Figure 7 *A* **disconformity** *exists where part of a sequence of parallel rock layers is missing. While often hard to see, a disconformity is the most common type of unconformity.*

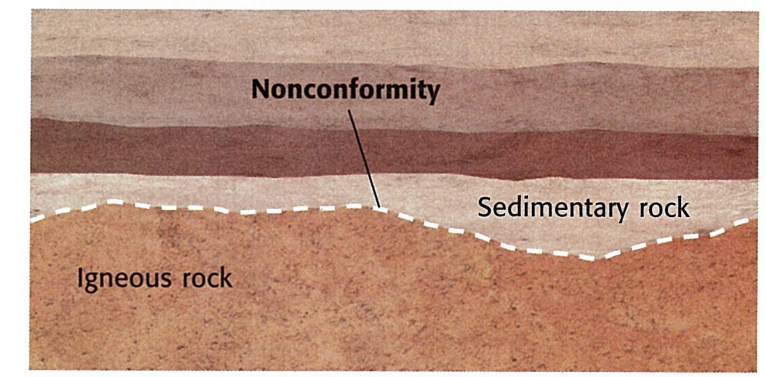


Figure 8 *A* **nonconformity** *exists where sedimentary rock layers lie on top of an eroded surface of nonlayered igneous or metamorphic rock.*

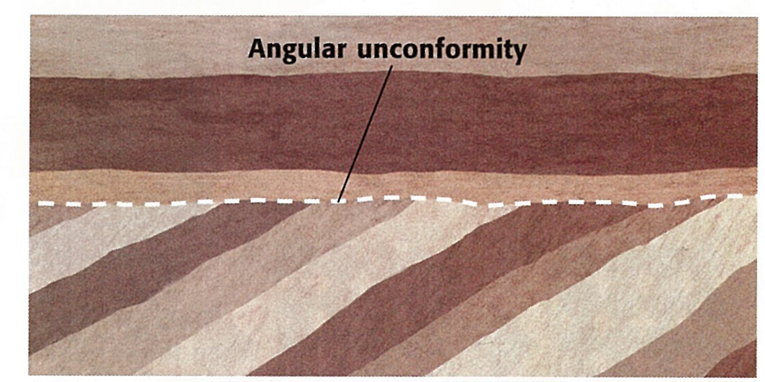


Figure 9 *An* **angular unconformity** *exists between horizontal rock layers and rock layers that are tilted or folded. The tilted or folded layers were eroded before horizontal layers formed above them.*