SECTION 2

Relative Dating

Key Concept Scientists can interpret the sequence of events in Earth's history by studying rock layers.

What You Will Learn

- The rock cycle includes the formation and recycling of rock.
- Relative dating establishes the order in which rocks formed or events took place.
- The principle of superposition states that younger rocks lie above older rocks if the layers are undisturbed.

Why It Matters

Determining the sequence of events in Earth's history helps determine the story of life and environmental changes on Earth.

Vocabulary

- relative dating
- sedimentary rock
- superposition
- unconformity
- law of crosscutting relationships

READING STRATEGY

Asking Questions Read this section silently. In your **Science Journal,** write down questions that you have about this section. Discuss your questions in a small group.

If you were a detective investigating a crime scene, what would you do? You might dust the scene for fingerprints or search for witnesses. As a detective, you must figure out the sequence of events that took place before you reached the crime scene.

Geologists have a similar goal when investigating Earth. They try to determine the order in which events have happened during Earth's history. But instead of relying on fingerprints and witnesses, geologists rely on rocks and fossils to help them. Determining whether an object or event is older or younger than other objects or events is called **relative dating.**

The Rock Cycle

Geologic history, from Earth's formation to the present, includes a record of rocks and of changes in life on Earth. This geologic history is sometimes called the *geologic record.* The rock cycle is an important process in the development of the geologic record. **Figure 1** shows how each type of rock can become any other type of rock through the rock cycle. For example, all rock can melt to form magma. *Igneous rock* forms when magma cools. *Metamorphic rock* forms when any type of solid rock changes into another type of rock because of temperature or pressure changes. **Sedimentary rock** is the kind of rock that forms from fragments of other types of rocks. Sedimentary rocks are the most useful rocks for relative dating.

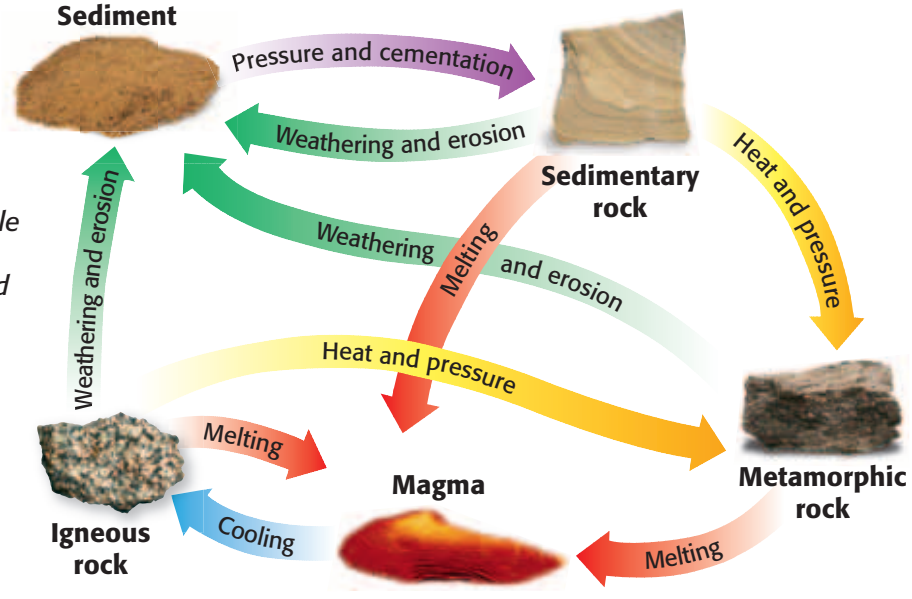


Figure 1 *The rock cycle is a series of geologic processes that form and recycle rock on Earth.*

Figure 2 *These mountains in Death Valley have been weathered, and the sediment has been eroded. The sediment has been deposited in a flat layer below the mountains.*

Weathering, Erosion, and Deposition

When rocks are exposed on Earth's surface, they can be broken down into smaller pieces, or *weathered*. Rocks can be weathered when physical processes crack and break the rock. Chemical weathering can take place as rock material reacts with water or air. Through weathering, all three rock types can break down to form sediment. *Sediment* is composed of rock fragments, material dissolved in water, and sometimes, biological debris.

Erosion is the process that moves sediment from one place to another. Water, wind, ice, and gravity can cause erosion. Eventually, sediment is deposited in a new location. Deposition is the process in which material is laid down or dropped. Because the sediment is loose when it is deposited, it settles into relatively flat layers. A new, flat layer of sediment rests on top of whatever rock or other sediment is already in place. So, new layers of sedimentary rock are almost always flat. The results of erosion and deposition in Death Valley in California are shown in **Figure 2.**

relative dating (REL uh tiv DAYT ing) any method of determining whether an event or object is older or younger than other events or objects

sedimentary rock (SED uh MEN tuhr ee RAHK) a rock that forms from compressed or cemented layers of sediment

Formation of Sedimentary Rock

After loose sediment is deposited, it may be *lithified,* or hardened, into sedimentary rock. In this process, the sediment is compacted and the grains of sediment are cemented together. Fossils form if biological debris or a trace of animal activity remains in a rock. The fossils are a record of the kind of life that existed where the sediment was deposited. And the type of rock that forms with a fossil can give clues about the environment in which the organism lived.

The type of rock that forms in any area depends on local conditions. So, no single rock layer is found in all areas of Earth. And during any one period of geologic time, many types of rock were forming in different areas of Earth. Therefore, no single area or history of an area can contain the geologic record for all of Earth.

7.3.c Students know how independent lines of evidence from geology, fossils, and comparative anatomy provide the bases for the theory of evolution.
7.4.c Students know that the rock cycle includes the formation of new sediment and rocks and that rocks are often found in layers, with the oldest generally on the bottom.

The Principle of Superposition

Suppose that you have a brother who takes a lot of pictures of your family and piles them in a box. Over the years, he adds 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?

Superposition in Rock Layers

Layers of sedimentary rock, such as the ones shown in **Figure 3,** are like stacked photographs. As you move from top to bottom, the layers get older. The principle that states that younger rocks lie above older rocks in undisturbed sequences is called **superposition.** Superposition helps geologists determine the relative ages of rock layers.

superposition
(soo puhr puh ZISH uhn) a principle that states that younger rocks lie above older rocks if the layers have not been disturbed

Superposition also helps geologists determine the relative ages of fossils. Fossils represent organisms that lived when sediment collected to form sedimentary rock. So, fossils found in a younger rock layer are younger than fossils found in an older rock layer. And fossils found in lower, or older, rock layers are older than fossils found in higher, or younger, rock layers.

Standards Check **What does the principle of superposition state about rocks that are found in layers?** **7.3.c, 7.4.c**

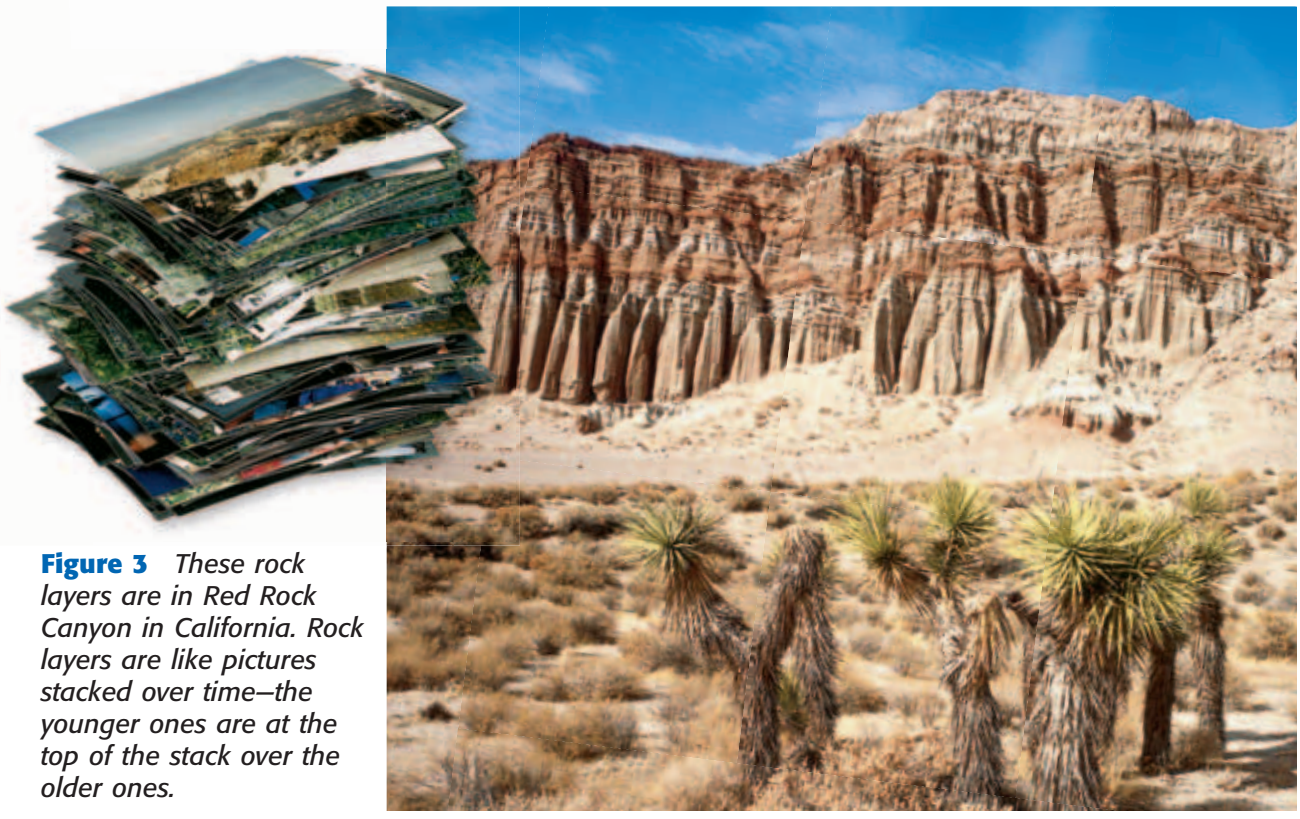
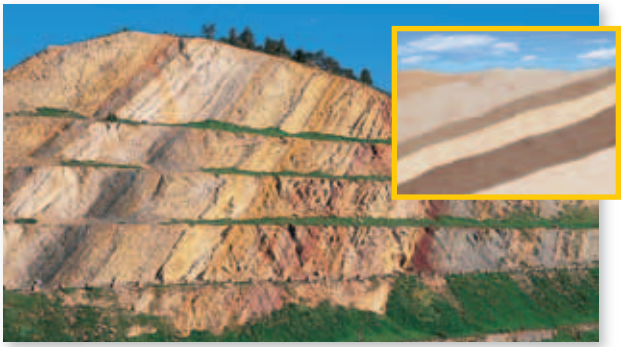


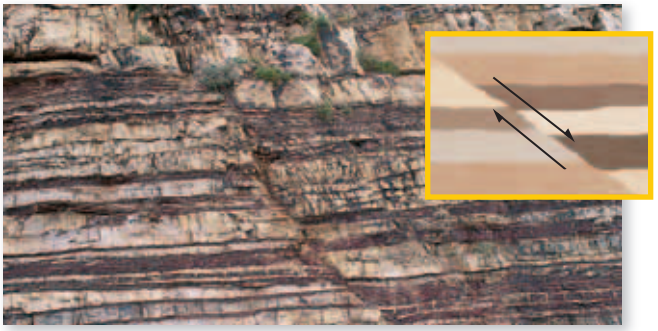
Figure 3 *These rock layers are in Red Rock Canyon in California. Rock layers are like pictures stacked over time—the younger ones are at the top of the stack over the older ones.*

Figure 4 How Rock Layers Become Disturbed

Folding *Folding* occurs when rock layers bend and buckle from forces inside Earth.



Tilting *Tilting* occurs when forces inside Earth slant rock layers.



Faults A *fault* is a break in Earth's crust along which blocks of rock slide relative to one another.

Intrusions An *intrusion* is molten rock from Earth's interior that squeezes into existing rock and cools.

Disturbed Rock Layers

Gravity causes sediment to be deposited in horizontal layers. So, if rock layers are not horizontal, something must have disturbed them after they formed. Sometimes, rock layers are even overturned by powerful forces in Earth's crust. In these sequences, older layers lie on top of younger layers.

Processes That Disturb Rock Layers

Folding and tilting are two events that disturb rock layers. *Folding* is the bending of rock layers that results from stress. *Tilting* happens when Earth's forces move rock layers so that they are slanted. Folding and tilting are shown in **Figure 4.**

Features That Cut Across Rock Layers

Geologists often find features that cut across existing layers of rock. These features include faults and intrusions. A *fault* is a break or crack in Earth's crust along which rocks shift position. An *intrusion* is a mass of igneous rock that forms when magma is injected into rock and then cools and solidifies. A fault and an intrusion are shown in **Figure 4.**

unconformity
(uhn kuhn FAWRM uh tee) a break in the geologic record created when rock layers are eroded or when sediment is not deposited for a long period of time

law of crosscutting relationships
(LAW UHV KRAWS KUHT ing ri LAY shuhn SHIPS) the principle that a fault or body of rock is younger than any other body of rock that it cuts through

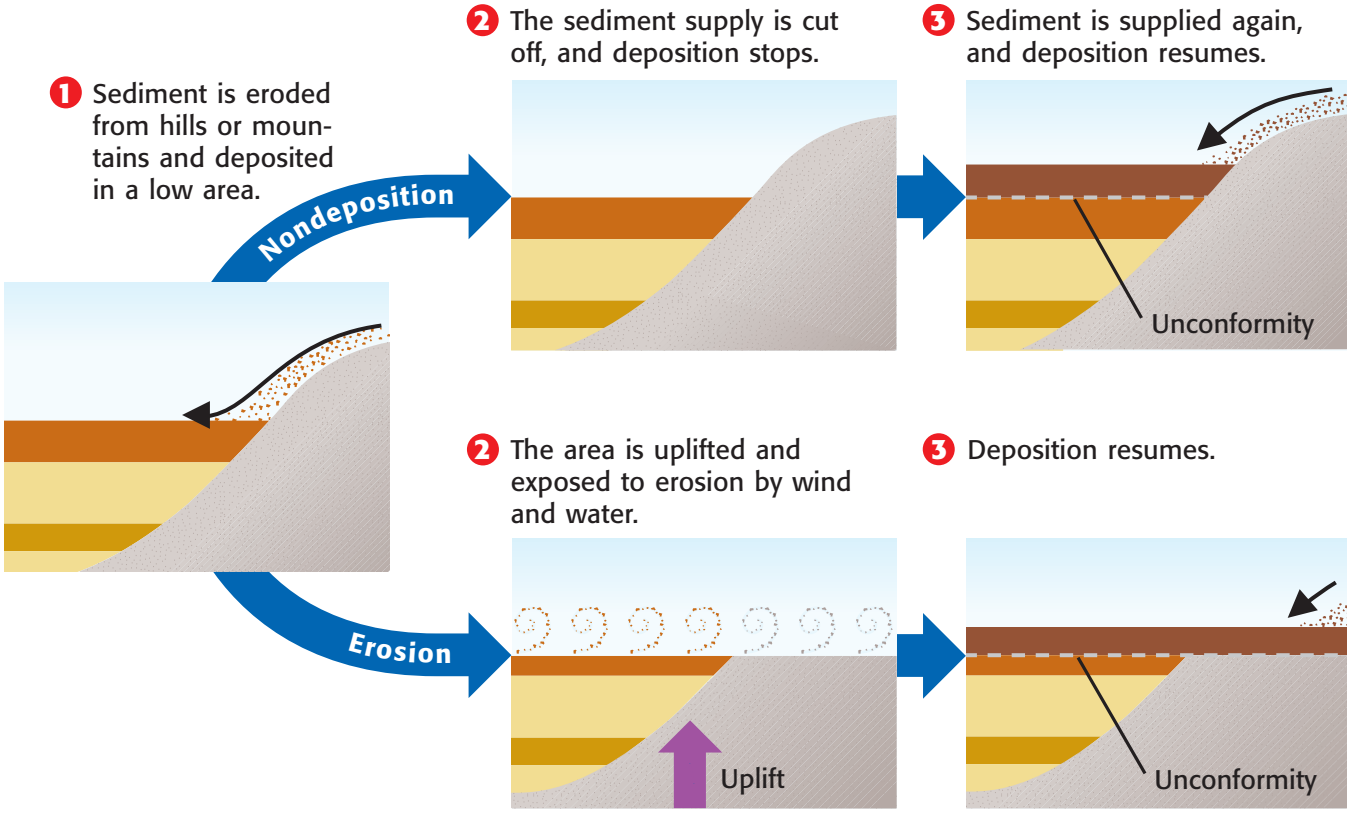
Gaps in the Record

Sometimes, layers of rock are missing, so there is 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 that you want to look at a paper you read 10 days ago. You know that the paper should be 10 papers deep in the stack. But when you look, the paper is not there. What happened? Perhaps you didn't put the paper in the stack. Or maybe someone removed the paper. The same principles apply to a missing rock layer and the missing newspaper.

Unconformities

Missing rock layers create breaks in rock-layer sequences. An **unconformity** is a surface that represents a break in or a missing part of the geologic record. Unconformities also represent missing time—time that was not recorded in layers of rock. When geologists find an unconformity, they question whether the "missing layer" was never present or whether it was there once and was somehow removed. Unconformities can form when deposition stops after a supply of sediment is cut off. Unconformities also form when erosion removes layers. **Figure 5** shows these two processes.

Figure 5 How Unconformities Form



Rock-Layer Puzzles

The principle of superposition states that younger layers of sedimentary rock are found on top of older layers if the layers have not been overturned. But what if the rock layers are more than just a stack of horizontal layers?

Geologists often find rock-layer sequences that have been affected by more than one process. Determining the order of events that led to the arrangement of these rock layers is like piecing together a puzzle. Geologists study rock-layer sequences to help piece together the history of Earth as told by the rock record.

The Law of Crosscutting Relationships

The **law of crosscutting relationships** states that a fault or a body of rock, such as an intrusion, is younger than any feature or layer of rock that the fault or rock body cuts through. For example, if a fault cuts through an unconformity, the fault is younger than the rock layers on either side of the unconformity. Remember that layers of rock have to be in place before anything can disturb them.

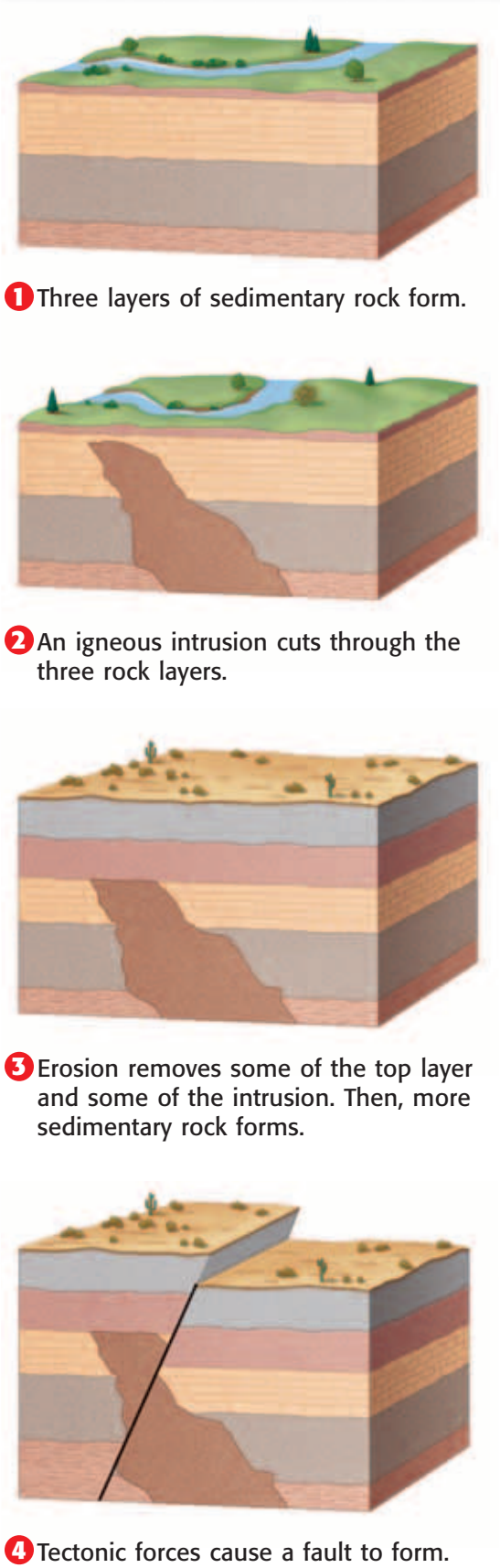
Standards Check **How does the law of crosscutting relationships help with relative dating of rock layers and features?** 7.4.c

Relative Ages of Rock Layers and Features

Figure 6 shows four stages in the formation of rock layers that contain an igneous intrusion, an unconformity, and a fault. A geologist studying rock layers has only the fourth view to look at when piecing together a rock-layer puzzle. Look at the bottom picture to see what the geologist is studying.

Now, start at the top to see the history of this area. You can see that the bottom three layers of sedimentary rock were formed first. Next, an intrusion cut through the three layers. The layers had to be there first before the intrusion could cut through them. An unconformity formed when the top of the sequence was eroded away. Then, two more layers of sediment were deposited. These layers were lithified and formed sedimentary rock. Finally, a fault cut through all of the sedimentary layers and the igneous intrusion.

Figure 6 **A Rock-Layer Sequence**



1 Three layers of sedimentary rock form.

2 An igneous intrusion cuts through the three rock layers.

3 Erosion removes some of the top layer and some of the intrusion. Then, more sedimentary rock forms.

4 Tectonic forces cause a fault to form.

SCHOOL to HOME

Looking at Rock Layers

With a parent or guardian, look at road cuts, beaches, or other areas where rock layers are visible. Sketch the rock layers in your **Science Journal.** Discuss which rock layers are the oldest with your parent or guardian. Hypothesize what processes have affected the rocks since the rocks formed.

ACTIVITY

Order of Events

Geologists use superposition and crosscutting relationships to find the relative ages of rocks. Relative dating makes clear the order in which events happened. But relative dating does not tell scientists exactly when those events took place.

To form a more complete picture of Earth's history, geologists combine relative dating with information that can establish actual dates. For example, imagine that you are digging in layers of soil at the edge of a river. You know from superposition that the layers near the top were deposited more recently than the layers farther down. But without more information, you can't tell when any of the layers were deposited. Now, imagine that in one layer, you find a coin dated 1965. You can now tell that the layer in which you found the coin could not have been deposited before 1965. And you know that the layers above the coin were deposited in 1965 or in a later year.

Standards Check **What information do geologists obtain from relative dating?** 7.4.c

Quick Lab

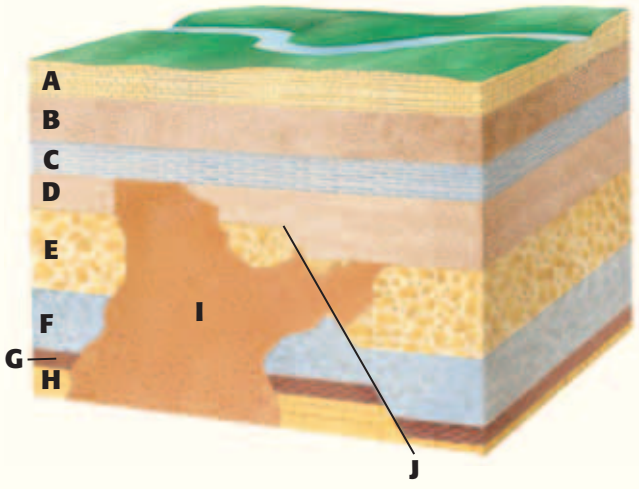
Solve a Rock-Layer Puzzle!

7.4.c

In this activity, you will put your scientific skills to work to determine the relative ages of the layers and features of this rock-layer puzzle.

Try It!

1. On a **piece of paper,** use a **pencil** to draw 10 horizontal lines. Write "Youngest" above the top line and "Oldest" below the bottom line.
2. Study the rock layers shown in the drawing to the right. Use what you know about superposition and crosscutting relationships to determine the order in which layers and features A through J formed.
3. List the oldest layer or feature on the bottom line, and list the youngest feature or layer on the top line.
4. Fill in all 10 letters to show the relative ages of all of the layers and features. When you have finished, each line should contain one letter.



Think About It!

5. Do the layers and features best represent geologic change as described by uniformitarianism or catastrophism? Explain your answer.
6. Can you tell how old any of the features or layers in this illustration are? If so, give the ages. If not, explain why not.

20 min