1 FOCUS

Section Objectives

12.11 **Describe** the geologic time scale.
12.12 **Explain** how use the geologic time scale is organized.
12.13 **Identify** some complications in dating rocks.

Reading Focus

Build Vocabulary L2

Paraphrase Tell students to list the vocabulary terms on a sheet of paper, leaving enough space for definitions. As they read, students should write the definitions in their own words.

Reading Strategy L2

Sample answers include:

The Geologic Time Scale
I. Structure of the Time Scale
  A. Divided into eons, eras, periods, and epochs
    1. *Phanerozoic* means "visible life."
    2. Three eras in the Phanerozoic: Paleozoic, Mesozoic, Cenozoic
    3. Cenozoic divided into epochs

12.4 The Geologic Time Scale

Reading Focus

Key Concepts

- What is the geologic time scale?
- How is the geologic time scale constructed?
- What are some complications in dating rocks?

Vocabulary

- geologic time scale
- eon
- era
- period
- epoch

Reading Strategy

Outlining As you read, make an outline of the important ideas in this section. Use the green headings as the main topics and fill in details from the remainder of the text.

The Geologic Time Scale
I. Structure of the Time Scale
A. ?
B. ?

Historians divide human history into certain periods, such as the Renaissance and the Industrial Revolution, based on human events. Thus you can produce a timeline of human history. Geologists have done something similar. **Based on their interpretations of the rock record, geologists have divided Earth's 4.56-billion-year history into units that represent specific amounts of time. Taken together, these time spans make up the geologic time scale.** The geologic time scale is shown in Figure 17. The major units of the time scale were described during the nineteenth century, principally by scientists working in Western Europe and Great Britain. Because radiometric dating was unavailable at that time, the entire time scale was created using methods of relative dating. It was only in the twentieth century that radiometric dating permitted numerical dates to be added.

Structure of the Time Scale

As shown in Figure 17, the geologic time scale is divided into eons, eras, periods, and epochs. **Eons represent the greatest expanses of time. Eons are divided into eras. Each era is subdivided into periods. Finally, periods are divided into still smaller units called epochs.** The eon that began about 540 million years ago is the **Phanerozoic,** a term derived from Greek words meaning "visible life." It is an appropriate description because the rocks and deposits of the Phanerozoic Eon contain abundant fossils that document major changes in life-forms over time.

Reading Checkpoint *What is the geologic time scale divided into?*

There are three eras within the Phanerozoic. The Paleozoic, which means "ancient life," the Mesozoic, which means "middle life," and the Cenozoic, which means "recent life." As the names imply, the eras are bounded by profound worldwide changes in life forms. **Each era is subdivided into periods, each of which is characterized by a somewhat less profound change in life forms as compared with the eras.**

Reading Checkpoint *What do each of the eras within the Phanerozoic Eon mean?*

The periods of the Cenozoic are divided into still smaller units called epochs. The epochs of other periods, however, are not usually referred to by specific names. Instead, the terms early, middle, and late are generally applied to the epochs of these earlier periods.

Precambrian Time

Notice that the detail of the geologic time scale doesn't begin until the start of the Cambrian Period, about 540 million years ago. The more than 4 billion years prior to the Cambrian is divided into eons, as shown in Figure 17. The common name for this huge expanse of time is the Precambrian. The view of the time scale on page 357 gives you a better idea of the expanse of time represented by the Precambrian.

Although it represents about 88 percent of Earth history, the Precambrian is not divided into nearly as many smaller time units as is the Phanerozoic eon. The reason is simple. Precambrian history is not known in great enough detail. The amount of information that geologists have acquired about Earth's past decreases substantially the farther back in time you go. **During Precambrian time, there were fewer life forms. These life forms are more difficult to identify and the rocks have been disturbed often.**

Reading Checkpoint *Why does detail in the geologic time scale begin at the Cambrian Period?*

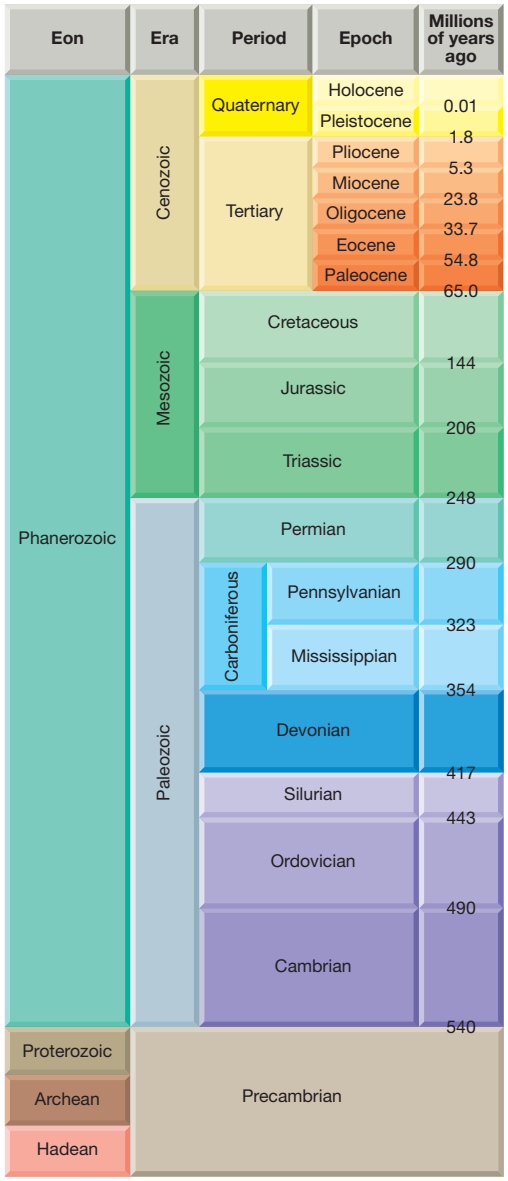

Figure 17 The Geologic Time Scale The numerical dates were added long after the time scale had been established using relative dating techniques.

2 INSTRUCT

Structure of the Time Scale

Use Visuals

L1

Figure 17 Make enlarged copies of the time scale so that all students can easily read it. Ask students to identify the era, period, and epoch in which they live. *(era: Cenozoic; period: Quaternary; epoch: Holocene)* Ask: **When did the Holocene Epoch began?** *(0.01 million years ago)*
Visual

Precambrian Time

Build Science Skills

L2

Classifying Have students use Figure 18 to classify the rock units according to the geologic period in which they belong. *(volcanic ash: Jurassic Period; Dakota sandstone, Mesaverde formation, and igneous dike: Cretaceous Period; Wasatch formation: Tertiary Period)*
Visual

Customize for Inclusion Students

Learning Disabled For students who have difficulty absorbing large blocks of text, use Figure 17 as a visual aid as you discuss the geologic time divisions. Consider adding benchmarks to the time scale to help students recall the various geologic divisions. For example, you could point out that mass extinctions mark the end of both the Paleozoic and Mesozoic eras. The first fish appear in the fossil record in the Ordovician Period; the first land plants appear in the Silurian Period.

Answer to . . .

Reading Checkpoint *eons, eras, periods, and epochs*

Reading Checkpoint *Paleozoic means "ancient life," Mesozoic means "middle life," and Cenozoic means "recent life."*

Reading Checkpoint *The time preceding the Cambrian is only divided into eons.*

Difficulties With the Geologic Time Scale

Integrate Language Arts L2

Recorded history is generally thought to have begun with the Sumerians, who developed cuneiform writing some 5000 years ago. Ask: **Assuming that Earth is 4.6 billion years old, what percentage of geologic time is represented by recorded history?** *(approximately 0.000001 percent)* **Logical**

Go Online NSTA SCILINKS

For: Links on the geologic time scale
Visit: www.SciLinks.org
Web Code: cjn-4125

Difficulties With the Geologic Time Scale

Although reasonably accurate numerical dates have been determined for the periods of the geologic time scale, the task is not easy. The basic problem comes from the fact that not all rocks can be dated by radiometric methods. For a radiometric date to be useful, all minerals in the rock must have formed at about the same time. For this reason, radioactive isotopes can be used to determine when minerals in an igneous rock crystallized and when pressure and heat made new minerals in a metamorphic rock.

However, samples of sedimentary rock can rarely be dated directly by radiometric means. **A sedimentary rock may contain particles that contain radioactive isotopes, but these particles are not the same age as the rock in which they occur.** The sediments that are eventually cemented together into a sedimentary rock have been weathered from older rocks. Radiometric dating would not be accurate since sedimentary rock forms from so many older rock particles.

Radiometric dating of metamorphic rocks may also be difficult. **The age of a particular mineral in a metamorphic rock does not necessarily represent the time when the rock first formed. Instead, the date may indicate when the rock was metamorphosed.**

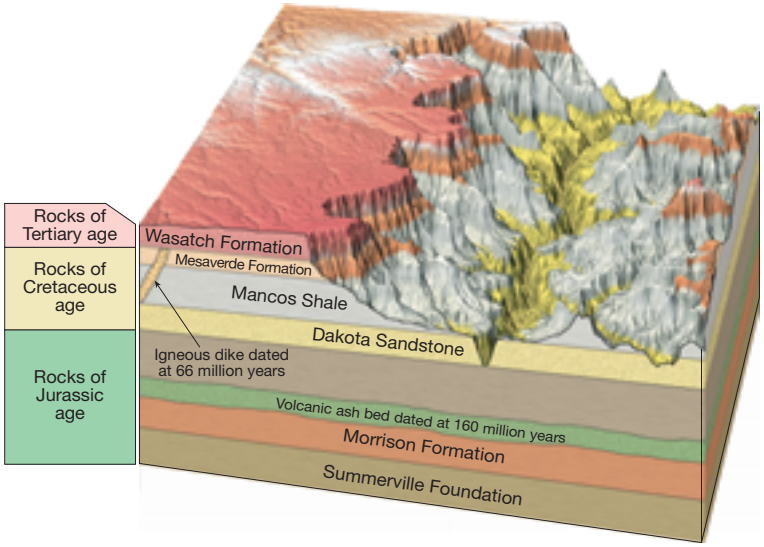

Figure 18 Using Radiometric Methods to Help Date Sedimentary Rocks
Numerical dates for sedimentary layers are usually determined by examining their relationship to igneous rocks.
Interpreting Illustrations ***Which of Steno's principles (pages 338–339) can you use to interpret the relative ages of these rock layers?***

Facts and Figures

With more research, scientists continue to refine the geologic time scale. Some may think that scientists would expect every date to be consistent with the current geologic time scale, but this is not true. In fact, the age of a particular sample and a particular geologic time scale only represent our current understanding. As more precise data are collected, scientists refine the time scale with smaller and smaller revisions. Who knows what the geologic time scale will look like one hundred years from now?

Go Online NSTA SCILINKS

Download a worksheet on the geologic time scale for students to complete, and find additional teacher support from NSTA SciLinks.

If samples of sedimentary rocks rarely produce reliable radiometric ages, how can numerical dates be assigned to sedimentary layers? Usually geologists must relate sedimentary rocks to datable igneous masses, as shown in Figure 18. In this example, radiometric dating has determined the ages of the volcanic ash bed within the Morrison Formation and the dike cutting the Mancos Shale and Mesaverde Formation. Both formations are igneous rock. The area covered by the Morrison Formation includes the following states: Montana, North and South Dakota, Nebraska, Kansas, Oklahoma, Texas, New Mexico, Arizona, Colorado, Utah, Wyoming, and Idaho. Using the principle of superposition, you can tell that the sedimentary beds below the ash are older than the ash, and all the layers above the ash are younger. Using the principle of cross-cutting relationships, you can see that the dike is younger than the Mancos Shale and the Mesaverde Formation. But the dike is older than the Wasatch Formation because the dike does not intrude the Tertiary rocks.

Reading Checkpoint

How can geologists overcome the problem of sedimentary rocks and dating the time units of the geologic time scale?

The Morrison Formation is one example of literally thousands that illustrates how datable materials are used to bracket the various episodes in Earth history within specific time periods. It shows the necessity of combining laboratory methods with field observations of rocks.

Section 12.4 Assessment

Reviewing Concepts

1. What is the geologic time scale?
2. What subdivisions make up the geologic time scale?
3. What is the basis on which the subdivisions are made?
4. What is the geologic time scale used for?
5. Why can it be difficult to assign dates to the divisions of the geologic time scale?

Thinking Critically

6. **Connecting Ideas** Explain how igneous intrusions and Steno's laws help geologists get around the problem of dating sedimentary rock layers.
7. **Inferring** What might have happened at the end of the Precambrian Eon and the beginning of the Phanerozoic Eon to allow geologists to mark this boundary on the time scale?

Connecting Concepts

Hypothesizing The boundaries of the geologic time scale are based on significant geologic events, while the epochs of the Cenozoic are based on the percentage occurrence of different fossil animals. Explain why you think it is possible to do this.

Build Reading Literacy L1

Refer to **p. 186D** in **Chapter 7,** which provides the guidelines for relating text and visuals.

Relate Text and Visuals Have students reexamine Figure 18 and give specific examples of how Steno's principles can be used to interpret the relative ages of rocks. For example, ask: **How might you tell if the igneous dike is older than the Wasatch formation?** *(If you could determine that the Mesaverde/Wasatch boundary is an unconformity.)*
Visual, Verbal

3 ASSESS

Evaluate Understanding L2

Have students brainstorm other ways to depict geologic time. For example, geologic time has been represented in calendars and on clocks.

Reteach L1

Have students list the three eras within the Phanerozic. *(Paleozoic, Mesozoic, Cenozoic)*

Connecting Concepts

The fossil record in the Cenozoic is more complete. Given this fact, it is possible to use changes in life forms to divide geologic time into epochs.

Section 12.4 Assessment

1. The geologic time scale divides Earth's history into units that each represent specific amounts of time.
2. eons, eras, periods, and epochs
3. Subdivisions are based on geologic events that are recorded in rocks and on changing life forms.
4. Geologists use the time scale to sequence important events in Earth's history. They also use it to assign relative ages to fossils and distinctive rock units.
5. Not all rocks can be dated by radiometric methods.
6. Sample answer: Geologists could date the intrusion using radiometric dating methods. They then could apply Steno's principles to assign relative ages to the units above and below the intrusion.
7. Sample answer: There was a huge change in the diversity and abundance of life forms at this boundary.

Answer to . . .

Figure 18 *law of superposition, principle of original horizontality, and principle of cross-cutting relationships*

Reading Checkpoint *Geologists can date igneous rocks, then determine how the igneous rocks relate to nearby sedimentary rocks.*