Name ______________________ Date ________________ Class __________

Fossils

Guide for Reading

- How do fossils form?
- What are the different kinds of fossils?
- What does the fossil record tell about organisms and environments of the past?

Fossils are the preserved remains or traces of living things. Fossils provide evidence of how life has changed over time. **Most fossils form when living things die and are buried by sediments. The sediments slowly harden into rock and preserve the shapes of the organisms.** Fossils are usually found in **sedimentary rock,** the type of rock that is made of hardened sediment.

Most fossils form from animals or plants that once lived in or near quiet water such as swamps, lakes, or shallow seas. When an organism dies, generally only its hard parts leave fossils. **Fossils found in rock include molds and casts, petrified fossils, carbon films, and trace fossils. Other fossils form when the remains of organisms are preserved in substances such as tar, amber, or ice.**

The most common fossils are molds and casts. A **mold** is a hollow area in sediment in the shape of an organism or part of an organism. A mold forms when the hard part of an organism, such as a shell, is buried in sediment. Later, water carrying dissolved minerals may seep into the empty space of a mold. If the water deposits the minerals there, the result is a **cast,** a solid copy of the shape of an organism. **Petrified fossils** are fossils in which minerals replace all or part of an organism. Another type of fossil is a **carbon film,** an extremely thin coating of carbon on rock. **Trace fossils** provide evidence of the activities of ancient organisms. Fossil footprints, trails, and burrows are examples of trace fossils. Some processes preserve the remains of organisms with little or no change. Organisms can be preserved in tar, amber, or ice.

Scientists who study fossils are called **paleontologists.** Paleontologists collect and classify fossils. Together, all the information that paleontologists have gathered about past life is called the fossil record. **The fossil record provides evidence about the history of life on Earth. The fossil record also shows that groups of organisms have changed over time.** It also reveals that fossils occur in a particular order, showing that life on Earth has evolved, or changed. Thus, the fossil record provides evidence to support the theory of evolution. A **scientific theory** is a well-tested concept that explains a wide range of observations. **Evolution** is the gradual change in living things over long periods of time. The fossil record shows that millions of types of organisms have evolved. Some have become extinct. A type of organism is **extinct** if it no longer exists and will never again live on Earth.

Fossils provide evidence of Earth's climate in the past. Paleontologists also use fossils to learn about past environments and changes in Earth's surface.

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Fossils

Understanding Main Ideas

Fill in the blanks in the table below.

Type of Fossil	Description
Petrified Fossil	Fossils in which **1.** ____________________ replace all or part of an organism
2. ____________________	A hollow area in sediment in the shape of an organism
3. ____________________	A solid copy of the shape of the organism
Carbon film	An extremely thin coating of **4.** ____________________ on rock
Trace Fossils	Evidence of the **5.** ____________________ of ancient organisms
6. ____________________	Remains of organisms in tar, amber, or ice

Answer the following questions on a separate sheet of paper.

7. Describe how a mold is related to a cast.
8. What can a paleontologist tell from fossil footprints of a dinosaur?
9. What does the fossil record reveal about the evolution of life on Earth?

Building Vocabulary

Fill in the blank to complete each statement.

10. The process by which all the different kinds of living things have changed over long periods of time is called ____________________.
11. The type of rock that is made of hardened sediment is called ____________________.
12. A type of organism is ____________________ if it no longer exists and will never again live on Earth.
13. A(n) ____________________ is a scientist who studies fossils.
14. The preserved remains or traces of living things are called ____________________.
15. A well-tested concept that explains a wide range of observations is called a(n) ____________________.

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The Relative Age of Rocks

Guide for Reading

- What is the law of superposition?
- How do geologists determine the relative age of rocks?
- How are index fossils useful to geologists?

The **relative age** of a rock is its age compared with the ages of other rocks. The **absolute age** of a rock is the number of years since the rock formed. The sediment that forms sedimentary rocks is deposited in flat layers. Over years, the sediment hardens and changes into sedimentary rock. These rock layers provide a record of Earth's geologic history.

It can be difficult to determine the absolute age of a rock. Geologists use the **law of superposition** to determine the relative ages of sedimentary rock layers. **According to the law of superposition, in horizontal sedimentary rock layers the oldest layer is at the bottom. Each higher layer is younger than the layer below it.**

There are other clues to the relative ages of rocks. **To determine relative age, geologists also study extrusions and intrusions of igneous rock, faults, and gaps in the geologic record.** Igneous rock forms when magma or lava hardens. Lava that hardens on the surface is called an **extrusion.** The rock layers below an extrusion are always older than the extrusion. Beneath the surface, magma may push into bodies of rock. There, the magma cools and hardens into a mass of igneous rock called an **intrusion.** An intrusion is always younger than the rock layers around and beneath it.

More clues come from the study of faults. A **fault** is a break in Earth's crust. A fault is always younger than the rock it cuts through. The surface where new rock layers meet a much older rock surface beneath them is called an **unconformity.** An unconformity is a gap in the geologic record. An unconformity shows where some rock layers have been lost because of erosion.

To date rock layers, geologists first give a relative age to a layer of rock at one location and then give the same age to matching layers at other locations. Certain fossils, called index fossils, help geologists match rock layers. To be useful as an **index fossil,** a fossil must be widely distributed and represent a type of organism that existed only briefly. **Index fossils are useful because they tell the relative ages of the rock layers in which they occur.** Geologists use particular types of organisms, such as ammonites, as index fossils. Ammonites were a group of hard-shelled animals that evolved in shallow seas more than 500 million years ago. They later became extinct. Ammonite fossils have been found in many different places.

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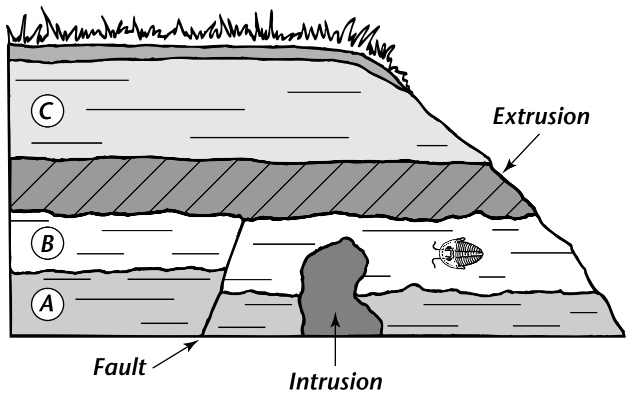
The Relative Age of Rocks

Understanding Main Ideas

Use the figure below to answer questions 1–4. Write your answers on a separate sheet of paper.



1. What is the youngest rock layer? Explain.
2. Is the extrusion older or younger than rock layer B? Explain.
3. Is the fault older or younger than rock layer A? Explain.
4. How could a geologist use the fossil in rock layer B to date a rock layer in another location?

Building Vocabulary

Match each term with its definition by writing the letter of the correct definition on the line next to the term.

____ **5.** fault

____ **6.** extrusion

____ **7.** unconformity

____ **8.** relative age

____ **9.** law of superposition

____ **10.** intrusion

____ **11.** absolute age

____ **12.** index fossil

a. the number of years since a rock has formed

b. a break in Earth's crust

c. the way to determine relative ages of rocks

d. a hardened layer of magma beneath Earth's surface

e. the age of a rock compared with the age of other rocks

f. fossils used to help geologists match rock layers

g. the surface where new rock layers meet a much older rock surface beneath them

h. a hardened layer of lava on Earth's surface

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Finding Clues to Rock Layers

Fossil clues give geologists a good idea of what life on Earth was like millions or even billions of years ago.

Problem

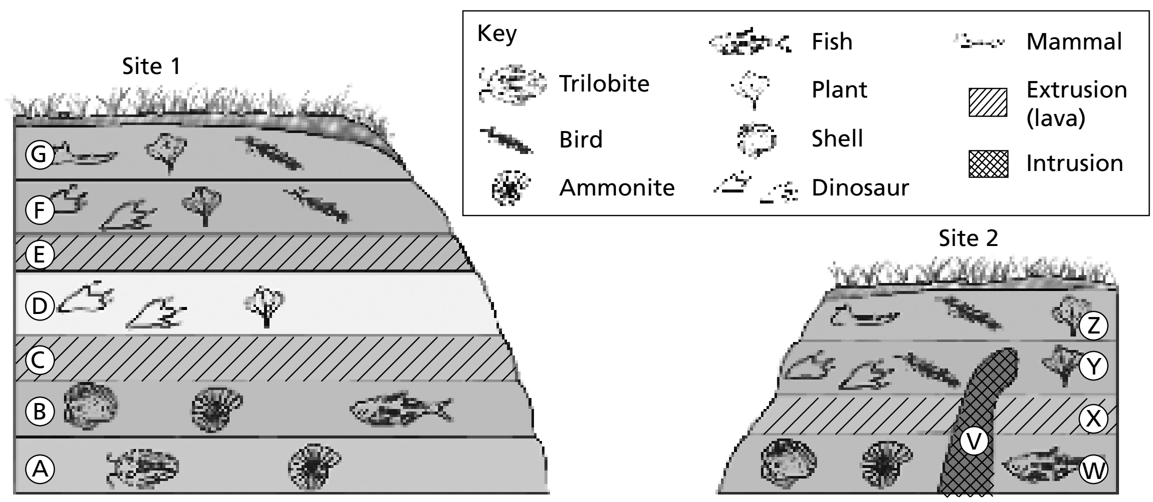
How can you use fossils and geologic features to interpret the relative ages of rock layers?

Skills Focus

interpreting data, drawing conclusions

Procedure

1. Study the rock layers at Sites 1 and 2. Write down the similarities and differences between the layers at the two sites.
2. List the kinds of fossils that are found in each rock layer of Sites 1 and 2.



Analyze and Conclude

Write your answers on the lines provided. Use a separate sheet of paper if you need more room.

Site 1

1. **Interpreting Data** What "fossils clues" in layers A and B indicate the kind of environment that existed when these rock layers were formed? How did the environment change in layer D?

____

____

2. **Drawing Conclusions** Which layer is the oldest? How do you know?

____

____

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3. **Drawing Conclusions** Which of the layers formed most recently? How do you know?

4. **Inferring** Why are there no fossils in layers C and E?

5. **Observing** What kind of fossils occurred in layer F?

Site 2

6. **Inferring** Which layer at Site 1 might have formed at the same time as layer W at Site 2?

7. **Relating Cause and Effect** What clues show an unconformity or gap in the horizontal rock layers? Which rock layers are missing? What might have happened to these rock layers?

8. **Interpreting Data** Which is older, intrusion V or layer Y? How do you know?

9. **Communicating** Write a journal entry describing how the environment at Site 2 changed over time. Starting with the earliest layer, describe the types of organisms, their environment, and how the environment changed.

More to Explore

Draw a sketch similar to Site 2, and include a fault that cuts across the intrusion. Have a partner then identify the relative ages of the fault, the intrusion, and the layers cut by the fault.

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Radioactive Dating of Rocks

Guide for Reading

- What happens during radioactive decay?
- What can be learned from radioactive dating?

Rocks are a form of matter. All the matter you see, including rocks, is made of tiny particles called **atoms.** When all the atoms of a particular type of matter are the same, the matter is an **element.** Most elements are stable. They do not change under normal conditions. But some elements exist in forms that are unstable. Over time, these elements break down, or decay, by releasing particles and energy in a process called **radioactive decay.** These unstable elements are said to be radioactive. **During radioactive decay, the atoms of one element break down to form atoms of another element.**

Radioactive elements occur naturally in igneous rocks. For an igneous rock, its "birthday" is when it first hardens to become rock. As a radioactive element within the igneous rock decays, it changes into another element. Therefore, the composition of the rock changes slowly over time. The amount of the radioactive element decreases. But the amount of the new element increases. The rate of decay of each radioactive element is constant—it never changes. This rate of decay is the element's half-life. The **half-life** of a radioactive element is the time it takes for half of the radioactive atoms to decay.

Geologists use radioactive dating to determine the absolute ages of rocks. In radioactive dating, scientists first determine the amount of a radioactive element in a rock. Then they compare that amount with the amount of the stable element into which the radioactive element decays. Scientists often use potassium-40 to date rocks. This form of potassium decays to form the stable element argon-40 and has a half-life of 1.3 billion years. The long half-life of potassium-40 makes it useful in dating the most ancient rocks.

All plants and animals contain some carbon-14, a radioactive form of carbon. Carbon-14 is useful in dating materials from plants and animals that lived as far back as 50,000 years ago. Because carbon-14 has a half-life of only 5,730 years, it can't be used to date more ancient fossils or rocks.

Radioactive dating works well for dating igneous rocks. Rock particles in sedimentary rocks are from other rocks, all of different ages. Radioactive dating would provide the ages of particles, not the sedimentary rock as a whole. But radioactive dating can be used to determine absolute dates of extrusions and intrusions near sedimentary rock layers. Sedimentary rock above an igneous intrusion must be younger than that intrusion.

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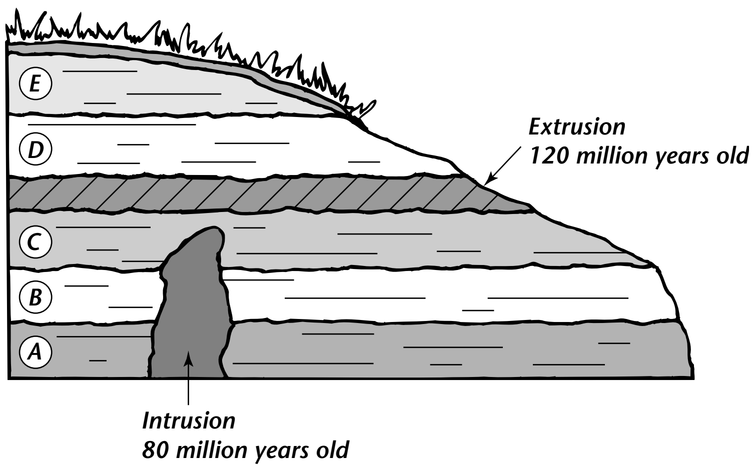
Radioactive Dating of Rocks

Understanding Main Ideas

Use the figure below to answer questions 1–3. Write your answers on a separate sheet of paper.



1. Can geologists use radioactive dating to find the absolute ages of sedimentary layers A, B, C, D, and E? Explain why or why not.
2. Can geologists use radioactive dating to find the absolute ages of the extrusion or the intrusion? Explain why or why not.
3. What is the age of rock layer C? Explain how you determined its age.

Building Vocabulary

Fill in the blank to complete each statement.

4. When all the atoms of a particular type of matter are the same, the matter is a(n) ______________________.
5. The time it takes for half of the atoms in a sample of a radioactive element to decay is called the element's______________________.
6. All matter is made of tiny particles called______________________.
7. During ______________________, the atoms of one element break down to form atoms of another element.

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The Geologic Time Scale

Guide for Reading

- Why is the geologic time scale used to show Earth's history?
- What are the different units of the geologic time scale?

Months, years, or even centuries aren't very helpful for thinking about Earth's long history. **Because the time span of Earth's past is so great, geologists use the geologic time scale to show Earth's history.** The **geologic time scale** is a record of the life forms and geologic events in Earth's history.

Scientists first developed the geologic time scale by studying rock layers and index fossils worldwide. With this information, scientists placed Earth's rock layers in order by relative age. Later, radioactive dating helped determine the absolute age of the divisions in the geologic time scale. As geologists studied the fossil record, they found major changes in life forms at different times. They used these changes to mark where one unit of geologic time ends and the next begins. Therefore, the divisions of the geologic time scale depend on the events in the history of life on Earth.

Geologic time begins with a long span of time called Precambrian Time. This span, which covers about 88 percent of Earth's history, ended 544 million years ago. **After Precambrian Time, the basic units of the geologic time scale are eras and periods.**

Geologists divide the time between Precambrian Time and the present into three long units called **eras.** These are the Paleozoic Era, the Mesozoic Era, and the Cenozoic Era.

Eras are subdivided into units of geologic time called **periods.** The names of the periods come from places around the world where geologists first described the rocks and fossils of each period.

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The Geologic Time Scale

Understanding Main Ideas

Put the following items in order from oldest (1) to most recent (4) by writing a number in the blank beside each.

__________ **1.** Mesozoic Era

__________ **2.** Precambrian Time

__________ **3.** Cenozoic Era

__________ **4.** Paleozoic Era

Rewrite the following sentence to make it true.

5. Geologists subdivide periods into eras.

____

____

Answer the following questions on a separate sheet of paper.

6. Why is the geologic time scale used to show Earth's history?

7. What methods did geologists use when they first developed the geologic time scale?

8. How did geologists decide where one division of the geologic time scale ends and the next begins?

Building Vocabulary

Fill in the blank to complete each statement.

9. Geologists divide the time between Precambrian Time and the present into three long units of time called __________________________.

10. The record of life forms and geologic events in Earth's history is called the __________________________.

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Early Earth

Guide for Reading

- When did Earth form?
- How did Earth's physical features develop during Precambrian Time?
- What were early Precambrian organisms like?

Scientists hypothesize that Earth formed at the same time as the other planets and the sun, roughly 4.6 billion years ago. According to this hypothesis, Earth collided with a large object. The collision threw a large amount of material from both bodies into orbit around Earth. This material combined to form the moon. Scientists think that Earth began as a ball of dust, rock, and ice in space. Gravity pulled this mass together. As Earth grew larger, its gravity increased, pulling in nearby dust, rock, and ice. As the growing Earth traveled around the sun, its gravity also captured gases such as hydrogen and helium. However, this first atmosphere was lost when the sun released a strong burst of particles.

During the first several hundred million years of Precambrian Time, an atmosphere, oceans, and continents began to form. After Earth lost its first atmosphere, a second atmosphere formed. The new atmosphere was made up mostly of carbon dioxide, nitrogen, and water vapor. Volcanic eruptions released carbon dioxide, water vapor, and other gases from Earth's interior. Collisions with comets added other gases to the atmosphere. A **comet** is a ball of dust and ice that orbits the sun.

At first, Earth's surface was too hot for water to remain as a liquid. All water evaporated into water vapor. However, as Earth's surface cooled, the water vapor began to condense to form rain. Gradually, rainwater began to accumulate to form an ocean. Over time, the oceans affected the composition of the atmosphere by absorbing much of the carbon dioxide.

Within 500 million years of Earth's formation, continents formed.

Scientists have found that the continents move very slowly over Earth's surface because of forces inside Earth. This process is called **continental drift.** The movement is slow—only a few centimeters per year. Over billions of years, Earth's landmasses have repeatedly formed, broken apart, and then crashed together again, forming new continents.

Scientists cannot pinpoint when or where life began on Earth. **But scientists have found fossils of single-celled organisms in rocks that formed about 3.5 billion years ago. These earliest life forms were probably similar to present-day bacteria.** Scientists hypothesize that all other forms of life on Earth arose from these simple organisms.

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Early Earth

Understanding Main Ideas

Put the processes that occurred in early Earth's history in the correct sequence by writing their letters in the correct order in the blanks.

A. Volcanic eruptions release carbon dioxide into the atmosphere.
B. Early organisms release oxygen into the air.
C. Oceans form on Earth's surface.
D. Hydrogen and helium are captured by gravity to form an atmosphere.
E. A dense, iron core forms at Earth's center.
F. Earth is a ball of dust, rock, and ice in space.

1. _________
2. _________
3. _________
4. _________
5. _________
6. _________

Answer the following questions on a separate sheet of paper.

7. What were the earliest life forms on Earth like?
8. What hypothesis explains why Earth and the moon are about the same age?
9. How did photosynthesis lead to the development of animals living on land?
10. How have scientists used radioactive dating to show that Earth is about 4.6 billion years old?

Building Vocabulary

Fill in the blank to complete each statement.

11. A _________________________ is a ball of dust and ice that orbits the sun.
12. The process in which the continents move very slowly over Earth's surface because of forces inside Earth is called _______________________ .

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Eras of Earth's History

Guide for Reading

- What were the major events in the Paleozoic Era?
- What were the major events in the Mesozoic Era?
- What were the major events in the Cenozoic Era?

During the Cambrian Period, life took a big leap forward. **At the beginning of the Paleozoic Era, a great number of kinds of organisms evolved.** At this time, all animals lived in the sea.

Many were animals without backbones, or **invertebrates.** Invertebrates such as jellyfish, worms, and sponges drifted through the water, crawled along the sandy bottom, or attached themselves to the ocean floors.

During this time, jawless fishes evolved. Jawless fishes were the first vertebrates. A **vertebrate** is an animal with a backbone. **During the Devonian Period, animals began to invade the land.** The first vertebrates to crawl onto land were lung fish with strong, muscular fins. The first amphibians evolved from these lung fish. An **amphibian** is an animal that lives part of its life on land and part of its life in water. Small reptiles developed during the Carboniferous Period. **Reptiles** have scaly skin and lay eggs with tough, leathery shells.

At the end of the Paleozoic Era, many kinds of organisms died out. This was a **mass extinction,** in which many types of living things became extinct at the same time. **The mass extinction at the end of the Paleozoic Era affected both plants and animals, on land and in the seas.** Scientists do not know what caused the mass extinction.

Scientists hypothesize that climate change resulting from continental drift may have caused the mass extinction at the end of the Paleozoic Era. **During the Permian Period, about 260 million years ago, Earth's continents moved together to form a great landmass, or supercontinent, called Pangaea.**

Some living things survived the mass extinction. Plants and animals that survived included fish, insects, reptiles, and cone-bearing plants called conifers. **Reptiles were so successful during the Mesozoic Era that this time is often called the Age of Reptiles.** About 225 million years ago, the first dinosaurs appeared. Mammals also first appeared during the Triassic Period. A **mammal** is a warmblooded vertebrate that feeds its young with milk.

At the close of the Cretaceous Period, about 65 million years ago, another mass extinction occurred. Scientists hypothesize that this mass extinction occurred when an object from space struck Earth.

The extinction of dinosaurs created an opportunity for mammals. During the Cenozoic Era, mammals evolved to live in many different environments—on land, in water, and even in the air.

Earth's climate cooled, causing a series of ice ages during the Quaternary Period.

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Eras of Earth's History

Understanding Main Ideas

Fill in the blanks in the table below.

Event	Time or Era	Event	Time or Era
Mass Extinction at end of Permian Period	**1.**	First reptiles appear	**6.**
Vertebrates evolve	**2.**	Pangaea forms	**7.**
Age of Mammals	**3.**	Mass extinction at end of Cretaceous Period	**8.**
Age of Reptiles	**4.**	First snakes appear	**9.**
First grasses appear	**5.**	First birds appear	**10.**

Answer the following questions on a separate sheet of paper.

11. What was the Cambrian Explosion?
12. Describe the probable causes of two mass extinctions.
13. What animal group was most successful during the Mesozoic Era?
14. What created an opportunity for mammals in the Cenozoic Era?
15. Describe what mammals faced in the Quaternary Period.

Building Vocabulary

Fill in the blank to complete each statement.

____ **16.** reptile
____ **17.** amphibian
____ **18.** mammal
____ **19.** vertebrate

a. animal that feeds its young with milk
b. animal with strong legs and eggs with thick shells
c. animal that evolved from lung fish
d. animal with a backbone

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EARTH SYSTEMS ESSENTIAL QUESTIONS

1. How do geologists know the age of rocks/fossils?

2. How do scientists use radiometric dating to know the age of fossils?

3. How do scientists use relative dating to identify the age of strata and fossils?

4. What is the Law of Superposition?