

BACKGROUND

Today, the rate of species extinctions is increasing. While extinction is an important step in evolution, today's rates of extinction are greater than the background (normal) rate. Extinction today is often related to habitat loss and environmental change. The rates of change are too fast for many species to adapt.

One way to better understand species responses to environmental change in the geologic past is to study fossils.

The broad field of paleontology includes the study of fossilized remains of life. These remains of life can include the organism itself as well as any evidence of its existence, such as trace fossils. Studying fossils can provide useful information about paleoenvironments, environmental change, and evolution.

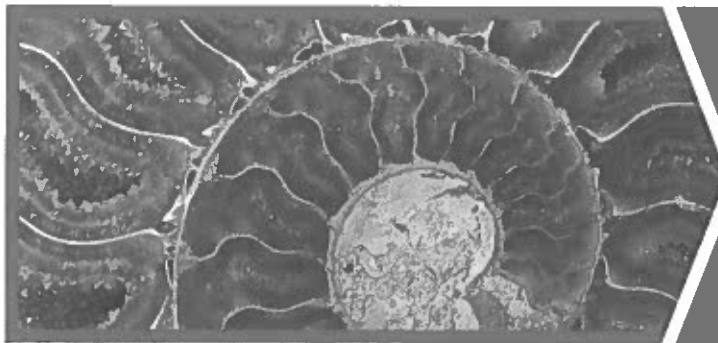
Fossilization is actually a relatively rare phenomenon. Certain conditions must be met in order for a fossil to be preserved. A fossil is most likely to be formed if the organism had hard parts, was rapidly buried by sediment, and was able to escape physical, chemical, and biological destruction after burial.

PART 1: TYPES OF FOSSILIZATION

There are several ways in which remains can be fossilized. The form in which the remains are fossilized provides information about the organism as well as the environment in which the fossil was formed.

There are seven types of fossilization:

- ♦ **Unaltered remains** are fossils that have hard parts that have remained unaltered. Soft parts can also be preserved given the right conditions, such as glacial ice or tar pits (i.e., La Brea Tar Pits) but are extremely rare in the fossil record.
- ♦ **Permineralization** occurs when minerals in water that flows through the porous materials of the tissues, wood, or bone material precipitate, filling in the once empty spaces. Permineralization is easily identified by the increased weight of the fossil resulting from areas that were previously air now being filled with minerals.



Brian Maashey/Shutterstock.com

4

Fossils,
Paleoenvironments,
and Relative Ages

- ♦ **Recrystallization** occurs when mineralogic changes happen over time. The original shape of the organism is preserved, but the cellular structure is lost during recrystallization. An example of recrystallization is when aragonite changes to calcite. Aragonite and calcite have the same chemical formula, but calcite is much more stable at Earth's surface than aragonite.
- ♦ **Molds** form when an organism gets buried and the original material is dissolved, but leaves an impression.
- ♦ **Casts** result when the impression left by a mold gets filled in with new sediment and hardens.
- ♦ **Replacement** occurs when the original material gets replaced on a molecular level (molecule by molecule). Examples are pyritization and silicification.
- ♦ **Carbonization** occurs when an organism dies, and most of the volatile organic materials disperse and leave a residue of coal-like carbon. This leaves a black film that preserves the outline and some detailed structure of the organism.

Inquiry Questions to be completed on a separate piece of paper before coming to class:

1. What might fossils tell you about past environments?
2. Do you think we might be undergoing a sixth mass extinction right now? Why or why not?

MATERIALS NEEDED FOR PART 1

- | | |
|-----------|-----------------------|
| ♦ Plaster | ♦ Fossil molds |
| ♦ Water | ♦ Container and spoon |
-

1 Activity

1. Select a mold from the options provided by the instructor.
2. Mix about one-half cup of plaster with enough water to make a thick yet workable paste.
3. Fill mold with plaster.
4. Jiggle the mold so that the plaster fills the mold evenly.
5. Let dry for about an hour and a half or until the plaster dries completely.
6. Pull the cast from the mold and you have now made a cast of the organism! (In nature a cast is formed when minerals or some other natural substance fills a mold.)

PART 2: RELATIVE DATING AND BIOSTRATIGRAPHIC SEQUENCING

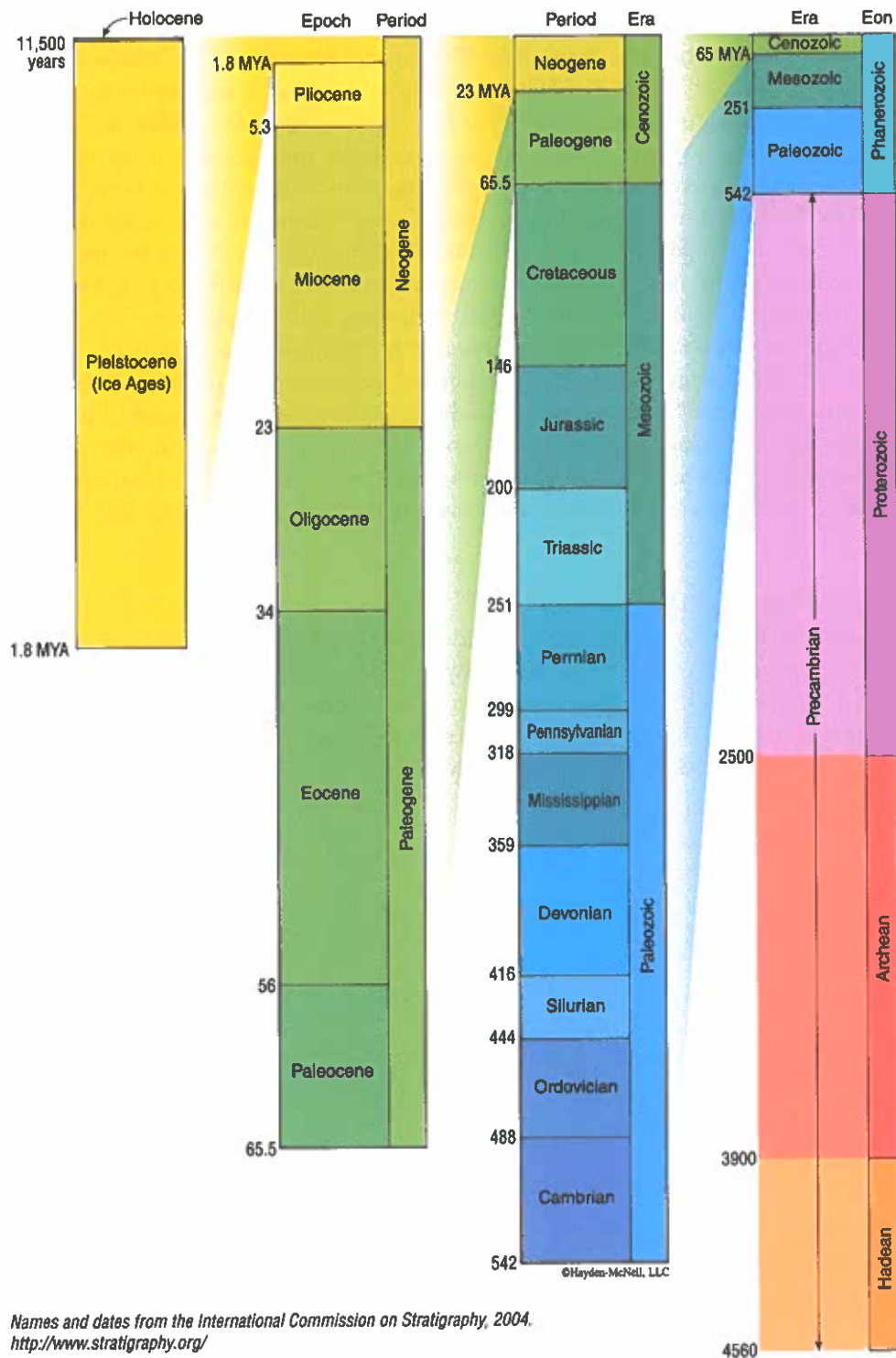


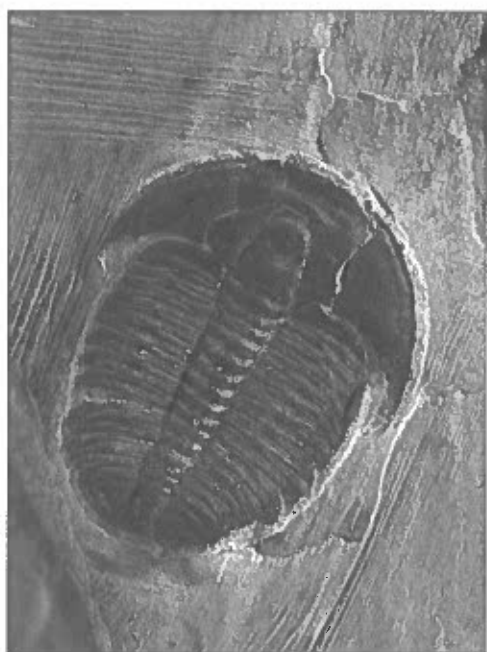
Figure 4-1. The geologic time scale

Geologic Timescale

Geologists agree that the earth is ~4.6 billion years old. Geologic time is first divided into four eons: Hadean, Archean, Proterozoic (collectively the Precambrian), and Phanerozoic (Figure 4-1). The Precambrian comprises about 90% of geologic time but relatively little is known about this eon. Geologists do know that the earth was formed prior to the Precambrian, and the subsequent events set the stage for life through the Phanerozoic. Since there is little fossil record in the Precambrian (disregarding stromatolites, which will be discussed later), this lab focuses on the Phanerozoic and the fossils left behind by the animals that lived during this time. It may seem a bit strange to focus so much attention on such a relatively small amount of time; however, by studying fossils, scientists are able to reconstruct details about the earth's past. Large shifts in the types of fossils found in an area may help to explain how the environment of an area changed over time. For example, if predominantly reptilian fossils are found in an area at a specific depth, and right above that depth there are exclusively mammalian fossils, some factor must have changed the environment to be more favorable for mammals compared to reptiles. Perhaps this change is local, but in some cases these changes represent larger regional and even global environmental change. If the fossils represent a worldwide shift toward mammals, it might be an indication of a mass extinction event. Such an event is noted in sediments and rocks around 65 million years ago where dinosaur fossils disappeared and were replaced by mammals (known as the K-T boundary extinction event). Though this may be one of the most well-known extinction events, it is only one of many and is a relatively small event in the history of life on Earth.

Biostratigraphy

Biostratigraphy focuses on correlating the relative ages of rock strata through fossil assemblages. Organisms commonly used for biostratigraphy include ammonites, graptolites, and trilobites (Figure 4-2). These fossils are considered index fossils because they are widespread geographically and they lived for only a short time. In the case of these specific species, they also happen to be easy to find in the rock record and easy to identify.



a) trilobite



b) ammonite

Figure 4-2. Examples of index fossils

A stratigraphic unit is a discrete rock layer that is fundamentally different than the layers both above and below in composition, depositional environment, or some other characteristic. Biostratigraphers document the fossils in a stratigraphic unit, and they assign a geologic age (or age span) to the organisms. Sometimes individual organisms span too long of a time period, and assemblages of organisms are used for greater precision.

The use of biostratigraphy and index fossils allows geologists to correlate rock units from different areas to better understand paleoenvironments (Figure 4-3). For example, by understanding the rock layers in the Grand Canyon, one can understand one local area, but by comparing the layers in the Grand Canyon National Park with those found in Bryce Canyon National Park and Zion National Park, an environmental history for a much larger geographic region begins to unfold.

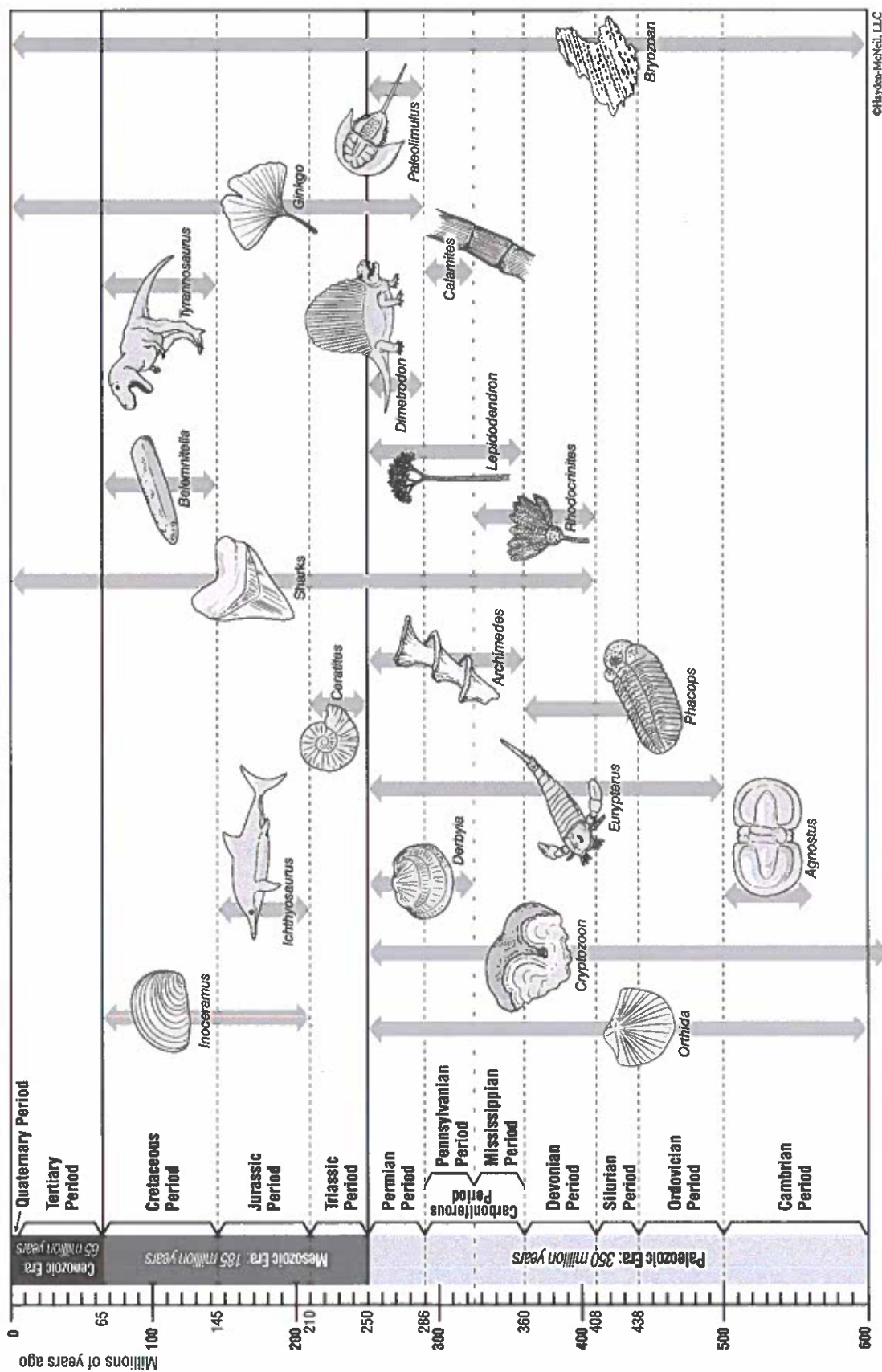


Figure 4-3. Example fossil correlation across geologic units

2 Activity: Biostratigraphy

For this section of the lab you may work in groups of 2–4 or as a class with your instructor to complete the activity. Follow the instructions below and complete the answer sheet to be turned in to your instructor.

1. Obtain the following materials from your instructor.
 - ♦ One felt board
 - ♦ One set of biostratigraphy fossils
2. The felt board should have three different colored layers labeled 1, 2, and 3.
 - ♦ In geologic layer 1 put the trilobite, crinoid, and rugose fossils.
 - ♦ In geologic layer 2 put the tyrannosaurus, triceratops, mosasaurs, iguanadon, turritella, and turtle fossils.
 - ♦ In geologic layer 3 put the mammoth, ground sloth, saber tooth tiger, turtle, and turritella fossils.
 - ♦ In geologic layer 4 put the *Homo sapien*, scleractinian coral, turtle, and turritella fossils.
3. Using the fossil identification chart, identify the ages of the fossils in each geologic time unit.
 - ♦ Using this information, determine the geologic age of each of the stratigraphic units.

PART 3: PAST AND MODERN CLIMATES

About 99.9% of all species that have ever lived on this planet are now extinct. Fantastic creatures, such as the dinosaurs, dominated this world for over 150 million years. Comparatively, humans have only been on this planet for about 100,000 years. The realization that anthropogenic influences on our planet may be the cause or accelerator in the extinction of species has led to the interest in **background extinction rates** and **mass extinction events**.

The background extinction rate refers to the steady dying out of families of organisms each million years. This steady disappearance of families, at a rate of between 2–4.6 per million years, is sometimes overlain by an increase in extinction to about 10 to 20 families per million years. These periods of increased extinction are referred to as mass extinctions.

The “Big Five”

There are five major mass extinction events in Earth’s history. Investigations into the causes of these extinctions can provide us with a more thorough understanding of our planet’s history and increased potential for predicting future environmental conditions.

Late Ordovician Extinction 440–450 mya

The late Ordovician extinction resulted in the disappearance of 57% of marine genera. Because warm adapted organisms disappeared, a global cooling event may have been to blame.

Late Devonian Extinction 360–375 mya

The late Devonian extinction resulted in an estimated loss of 75% of species in the oceans, including giant reef communities and armored jawless fish. A severe cooling event could have wiped out the tropical reefs and other warm-adapted organisms.

Permian Extinction 251 mya

The Permian extinction was by far the largest extinction event in the history of our planet. The Permian extinction resulted in the loss of 96% of the species in the marine realm and 75% of land vertebrates. The best evidence for this extinction is found in marine rocks. Some of the species lost include the trilobites, blastoids, tabulate corals, rugose corals, orthid brachiopods, and archaic mollusks. The radical change in the faunal communities resulted in what was known as the transition from “Paleozoic fauna” (crinoid-coral-bryozoan dominated) to the “modern fauna” that still dominates the seafloor today.

Late Triassic Extinction 199 mya

Another extinction at about 199 million years ago eliminated about half of the species that were known to have existed at that time, including the conodonts and 20% of families in the marine realm. This extinction event, called the Triassic–Jurassic extinction, is thought to have opened up ecological niches that resulted in the proliferation of the dinosaurs, allowing them to assume

the dominant roles in the Jurassic. Some proposed explanations for this event include gradual climate change or sea-level fluctuations, however this does not explain the suddenness of the extinctions in the marine realm; an asteroid impact, but no impact crater has been found at the Triassic–Jurassic boundary; or volcanism. Increases in volcanism would result in the release of carbon dioxide or sulfur dioxide and aerosols, which could cause global climate change.

Cretaceous–Tertiary (K–T) Extinction 65 mya

The K–T extinction event is famous for having wiped out the dinosaurs. Along with the dinosaurs went ammonites, marine reptiles, most marine plankton, and many marine vertebrates. Several causes of this extinction have been proposed; however, after the discovery of the Chicxulub crater in the northern Yucatan Peninsula of Mexico in 1978 it became clear that a meteorite impact and all of the environmental consequences that brings (i.e., tsunami, molten quartz raining from the sky, worldwide wild fires, etc.) were the cause of this extinction event. The impact itself would have thrown ash up into the atmosphere, blocking out the sun and causing long dark periods. This may have resulted in the collapse of land plants, causing a broken link in the food chain. These dark and cold periods would have tremendously affected the cold-blooded dinosaurs and marine reptiles, helping fuel their demise. Acid rain, volcanic activity, and the ash thrown into the atmosphere by the meteorite impact would have been raining down on organisms. This addition of acidity to the surface of the ocean is thought to be a cause in the extinction of marine plankton but would also have affected land organisms, perhaps making burrowing one of the few means of escape. With conditions during the K–T extinction, it is not surprising that many organisms went extinct—it is more astonishing that anything made it through unharmed.

Pleistocene Extinction ~10,000 ya

Although this extinction is not typically considered one of the “Big Five,” it is frequently discussed due to its proximity to the evolution of hominids (humans and human ancestors). This extinction involved the disappearance of the large land mammals concentrated at about 11,000 years ago. Large megafauna such as the woolly mammoth, mastadons, ground sloths, glyptodonts, saber-tooth cats, giant bears, and dire wolves suddenly disappear from the geologic record. Some schools of thought attribute the disappearance of the large megafauna to overhunting by humans. Others blame the transition from the last glacial maximum to the present interglacial. It is possible that a combination of these two hypotheses may be the actual root cause of the Pleistocene extinction.

Modern Extinctions

Many scientists believe the earth is undergoing the sixth major mass extinction due to anthropogenic changes to habitat and biodiversity, and is often linked to modern-day climate change.

3 Activity: Mass Extinctions

For this exercise you may work in groups or as a class.

1. Obtain the following materials from your instructor.
 - ♦ One felt board
 - ♦ One set of mass extinction fossils
 - ♦ Felt line
2. Using the felt board, place the following fossils in the specified geologic layers:
 - ♦ **Layer 1**—stegosaurus, allosaurus, pterosaurs, turtles, ammonite, megazostrodon, archaeopteryx
 - ♦ **Early (Cret) Layer 2**—iguanodon, pterosaurs, turtles, ammonite, archaeopteryx, triceratops, graptolites
 - ♦ **Late Layer 3**—mosasaurs, anagaloidea, pterosaurs, turtles, archaeopteryx, ammonite, tyrannosaurus, triceratops, graptolites
 - ♦ **Layer 4**—anagaloidea, turtles, graptolites
3. Using the felt line, indicate the point in the rock layer at which the mass extinction occurred.
4. Using the description of the “Big Five” mass extinctions, determine which extinction event is represented in this exercise and give it a geologic age.

PART 4: DETERMINING RELATIVE TIME

First and last appearances of fossils can provide age constraints on different geologic units; however, fossils are generally only found in certain types of sedimentary rocks. In metamorphic and igneous rocks chemical measurements are usually needed to determine the age of the rock unit. These methods often involve the use of radiometric clocks. These clocks utilize principles of radioactive decay. In many cases, simply understanding the sequence of events in a series of geologic units or outcrops can be very helpful. Determining the sequence of events can also be described as the assignment of relative ages. In other words, which events happened first, last, and in between.

Using the following principles (you also used these during the candy bar activity—Scientific Method), work in small groups to determine the sequence of events, from oldest to youngest, in the block diagram provided by your instructor.

Activity 2: Biostratigraphy

1. Geologic age of the stratigraphic units

Layer 1: _____

Layer 2: _____

Layer 3: _____

Layer 4: _____

2. What is an index fossil and how is it used to identify stratigraphic units?

3. Name three factors that make a good index fossil.

Activity 3: Mass Extinction

1. In what layer is the extinction event located?

2. What is the geologic age of the extinction event?

3. What extinction event is represented in the exercise?

4. What are possible causes of this extinction event?

- ## Activity 4: Relative Dating

33

