SCOPE, SEQUENCE, and COORDINATION

A National Curriculum Project for High School Science Education

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National Science Education Standard—Earth and Space

The Origin and Evolution of the Earth System

Evidence for one-celled foms of life—the bacteria—extends back more than 3.5 billion years. The evolution of life caused dramatic changes in the composition of the Earth's atmosphere, which did not originally contain oxygen.

Teacher Materials

Learning Sequence Item:

1007

Fossils and Lithologic Units

May 1996
Adapted by: Tom Hinojosa

Evolution of Life, Bacteria and Algae, and Oxygen in the Atmosphere. Students should study the stages of evolution through an examination of fossils and lithologic units. Statistical analysis will help students determine how species analysis is conducted in a paleontologist manner. In this case, form and function are linked together along with environmental characteristics. *(Earth and Space Sciences, A Framework for High School Science Education, p. 154.)*

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2. Reading the Rocks
3. A Timely Story
4. Time on the Line
5. A Darwinian Dilemma

This micro-unit was adapted by **Tom Hinojosa** (SS&C Center Coordinator, Santa Clara, Calif.)

1007

Learning Sequence

Evolution of Life, Bacteria and Algae, and Oxygen in the Atmosphere. Students should study the stages of evolution through an examination of fossils and lithologic units. Statistical analysis will help students determine how species analysis is conducted in a paleontologist manner. In this case, form and function are linked together along with environmental characteristics. *(Earth and Space Sciences, A Framework for High School Science Education, p. 154.)*

Science as Inquiry	Science and Technology	Science in Personal and Social Perspectives	History and Nature of Science
A Journey Through Time **Activity 1** A Traditional Layer Cake **Activity 2** Rock and Rolling Rivers **Activity 3** Ruffles Aren't Ridges **Activity 4** All Things in Due Time **Assessment 1** Reading the Rocks **Assessment 2** A Timely Story **Assessment 3** Time on the Line **Assessment 4**			A Darwinian Dilemma **Assessment 5**

Suggested Sequence of Events

Event #1

Lab Activity

1. A Journey Through Time (30–60 minutes)

Alternative or Additional Activities

2. A Traditional Layer Cake (30–40 minutes)

Event #2

Lab Activity

3. Rock and Rolling Rivers (40–50 minutes)

Event #3

Lab Activity

4. Ruffles Aren't Ridges (45–60 minutes)

Event #4

Readings from Science as Inquiry, Science and Technology, Science in Personal and Social Perspectives, and History and Nature of Science

Suggested readings:

Kerr, Richard A., "Animal Oddballs Brought into the Ancestral Fold?" *Science,*Vol. 270, No. 5236, Oct. 27, 1995, pp. 580–581.

Nashi, J. Madeleine, "How Did Life Begin?" *Time* Magazine, Vol. 142, No. 15, Oct. 11, 1993, pp. 68–74.

Monastersky, Richard, "The Ediacaran Enigma," *Science News*, Vol. 148, No. 2, July 8, 1995, pp. 28–30.

Assessment items are at the back of this volume.

Assessment Recommendations

This teacher materials packet contains a few items suggested for classroom assessment. Often, three types of items are included. Some have been tested and reviewed, but not all.

1. Multiple-choice questions accompanied by short essays, called justification, that allow teachers to find out if students really understand their selections on the multiple choice.

2. Open-ended questions asking for essay responses.

3. Suggestions for performance tasks, usually including laboratory work, questions to be answered, data to be graphed and processed, and inferences to be made. Some tasks include proposals for student design of such tasks. These may sometimes closely resemble a good laboratory task, since the best types of laboratories are assessing student skills and performance at all times. Special assessment tasks will not be needed if measures such as questions, tabulations, graphs, calculations, etc., are incorporated into regular lab activities.

Teachers are encouraged to make changes in these items to suit their own classroom situations and to develop further items of their own, hopefully finding inspiration in the models we have provided. We hope you may consider adding your best items to our pool. We also will be very pleased to hear of proposed revisions to our items when you think they are needed.

Science as Inquiry

A Journey Through Time

What ancient events changed life on Earth for all time?

Overview:

Students map various organisms/life forms on to a geologic time scale. This timeline will be used in Activity 2, following this activity.

Materials:

Per lab group:
paper, at least 1-meter long (adding machine tape)
colored pencils, 5

Procedure:

Students work alone or in pairs. They make use of a basic time line, mapping on it important events related to the stages of evolution. You may wish to have them color-code events to the appropriate time period/ time-line segment using colored pencils. Students fill in each portion of the timeline with a different color and color-code each event by using the same colors as they map on each event.

Background:

The Earth was born 4.5 billion years ago. Comprehending that vastness in time is no easy task. John McPhee, in his book, Basin and Range, recounts a nice illustration of what this sort of time means. Stand with your arms held out to each side and let the extent of the Earth's history be represented by the distance from the tips of your fingers on your left hand to the tips of the fingers on your right. Now, if someone were to run a file across the fingernail of your right middle finger, then the time that humans have been on Earth would be erased.

Nearly 4,000-million years passed after Earth's inception before the first animals left their traces. This stretch of time is called the Precambrian. To speak of the Precambrian as a single unified time period is misleading—for it makes up roughly seven-eighths of the Earth's history. During the Precambrian, the most important events in biological history took place. Consider that the Earth formed, life arose, the first tectonic plates formed and began to move, eukaryotic cells evolved, the atmosphere became enriched in oxygen—and just before the end of the Precambrian, complex multicellular organisms, including the first animals, evolved.

The history of Earth is broken up into a hierarchical set of divisions for describing geologic time. As increasingly smaller units of time, the generally accepted divisions are eon, era, period, epoch, and age. The Phanerozoic Eon represents the time during which the majority of macroscopic organisms, i.e., algae, fungal, plants and animals lived. When first proposed as a division of geologic time, the beginning of the Phanerozoic (approximately 540-million years ago) was thought to coincide with the beginning of life. In reality, this eon coincides with the appearance of animals that evolved external skeletons, like shells, and the later animals that formed internal skeletons, such as the bony elements of vertebrates.

The Phanerozoic is divided into three major divisions, the Cenozoic, Mesozoic, and Paleozoic eras. The "zoic" part of the word comes from the root "zoo," which means animal. This is the same root as in the words Zoology and Zoological Park (or Zoo). Further, "Cen" means recent, "Meso" means middle, and "Paleo" means ancient. These divisions reflect major changes in the composition of ancient faunas—each era being recognized by its domination by a particular group of animals. The Cenozoic has sometimes been called the "Age of Mammals," the Mesozoic, the "Age of Dinosaurs" or reptiles, and the Paleozoic, the "Age of Fishes" or invertebrates. This is an overly simplified view, but one which has some value for the newcomer. For instance, other groups of animals lived during the Mesozoic. In addition to the dinosaurs, mammals, turtles, crocodiles, frogs, salamanders, and countless varieties of insects also lived on land. Additionally, there were many kinds of plants living in the past that no longer live today, and many ancient floras went through great changes, too—but not always at the same time that the animal groups changed.

Since Darwin's time, the fossil history of life on Earth has been pushed back to 3.5 billion years before the present. Most of these fossils are microscopic bacteria and algae. However, in the latest Precambrian—a time period now called the Vendian, or the Ediacaran, and lasting from about 650 to 540 million years ago—macroscopic fossils of soft-bodied organisms can be found in a few localities around the world.

Most Precambrian organisms were microscopic bacteria and algae. Some of these organisms built algal reefs called stromatolites. Stromatolites are made of alternating thin layers of silt that settled from the water, and calcium carbonate made by algae. Stromatolites are thought to have been a major source of oxygen that resulted in the explosion of life in Cambrian time. Found in intertidal or shallow-water areas, they were ideally situated to make use of the water, carbon dioxide atmosphere, and intense sunlight needed to carry-out photosynthesis which produced oxygen as a by-product. The oxygen they produced accumulated over the millennia to form the kind of oxygen-rich atmosphere that we know today. The lives of all animals depend on it. We need it not only to breathe but to protect us. Oxygen in the atmosphere forms the ozone screen which cuts off most of the ultraviolet rays of the sun. These were the very rays which provided energy to synthesize amino acids and sugars in the primordial oceans, so the arrival of blue-greens ruled out the possibility that life on earth could ever begin in the same way again.

Variations:

Additional events could be added to the timeline. A much larger (wall-sized) timeline could be constructed, having students create illustrations of sample fossils from each era and pasting them appropriately on the timeline. If you have a reference book for identifying fossils, you could make it into a game by giving students illustrations of unidentified fossils and having them look up for proper placement of these fossils on the timeline. This could be made into a short research project by having students do their own research both naming and describing the organism represented by sample fossils and creating a short write-up to go with each posting on the timeline.

Adapted from:
Attenborough, David, Life on Earth, Boston: Little, Brown and Company, 1979.
Internet: http://ucmp 1.berkeley.edu, May 1996: The Museum of Paleontology of the University of California at Berkeley and the Regents of the University of California, 1994.
Spaulding, N. E., S. N. Namowitz, Earth Science, Lexington, Mass.: D. C. Heath and Company, 1994.
Zihlman, Adrienne L., The Human Evolution Coloring Book, New York: Harper & Row, Publishers, Inc., 1982.

an alternative activity for Event 1

Teacher Sheet

Science as Inquiry

A Traditional Layer Cake

What conclusions can be reached by studying sedimentary rock layers?

Overview:

This is an optional activity for students who may need more experience with the concept of sedimentation. In Part A, students simulate the formation of sedimentary rock and consider how fossils might be found in such rock formations. In Part B, students think critically to determine fact or inference when examining sedimentary layers embedded with fossils.

Materials:

Per lab group:
jar (large—pickle or mayonnaise jar)
sand, fine, 50–100 mL
gravel, coarse, 50–100 mL
rocks, small, (0.5–1.0 mm dia.), 50–100 mL
humus, 50–100 mL
clay, dry powdery, 50–100 mL
shell fragments of various sizes (approx. 1 mm dia.), 50–100 mL
Optional: 10–12 bone fragments from an owl pellet

Procedure:

Part A. Students partially fill large jars with fine sand, coarse gravel, small rocks, humus, and clay. If possible, try to include several different textures and colors of materials for visual effects. Include some shells, small pieces of bone (like from an owl pellet) or toy dinosaurs in this muddy mixture to simulate remains of organisms. The container should be filled with water so that all this material represents a muddy stream. The students will shake the jar and then let it stand, noting the size and kinds of materials which settle to the bottom first. Students should explain in their notes how shells might be found in sedimentary rock based upon this model and their observations.

Part B. Students will examine the rock sample shown as a diagram on the student page. They will then consider several statements about the rock sample and decide if they are inference or fact. They will also consider what events could alter the rock arrangement and how such changes could confuse the study of such rock samples. Students are not given a definition for “fact.” Encourage discussion by class members to arrive at a reasonable definition for both “fact” and “inference.” The activity will help students clarify the distinction in their own minds.

Background:

If jars are prepared before class, Part A can be done in 10–15 minutes.

The first people who needed to understand the geological relationships of different rock units were miners. Mining had been of commercial interest since at least the days of the Romans, but it wasn’t until the 1500s and 1600s that these efforts produced an interest in local rock relationships.

By noting the relationships of different rock units, Nicolaus Steno in 1669 described two basic geologic principles. The first stated that sedimentary rocks are laid down in a horizontal manner, and the second stated that younger rock units were deposited on top of older rock units. To envision this latter principle, think of the layers of paint on a wall. The oldest layer was put on first and is at the bottom, while the newest layer is at the top. An additional concept was introduced by James Hutton in 1795, and later emphasized by Charles Lyell in the early 1800s, was the idea that natural geologic processes were uniform in frequency and magnitude throughout time. This principle has been referred to as the “law of uniformitarianism.”

Steno’s principles allowed workers in the 1600s and early 1700s to begin to recognize rock successions. However, because rocks were locally described by the color, texture, or even smell, comparisons between rock sequences of different areas were often not possible. It was the use of fossils that provided the opportunity for workers to correlate between geographically distinct areas. This contribution was possible because fossils are widely found in areas of the Earth’s crust.

For the next major contribution to the geologic time scale, we turn to William Smith, a canal builder and geologist from England. In 1815 Smith produced a geologic map of England in which he successfully demonstrated the validity of the principle of faunal succession. This principle simply stated that fossils have a very definite order in which they are found in rocks. This principle led others that followed to use fossils to define increments within a relative time scale.

Variations:

Use actual rock samples containing fossil remains along with the illustration in the student sheet for Part B if possible. Students may be asked to write a story about the fossil-bearing rock in Part B and share it with the class.

Colored aquarium gravel can be used in Part A to enhance the results.

Adapted from:

Dombrowski, J., and A. Sullivan, *Evolution—A Context for Biology*. The Howard Hughes Medical Institute for High School Teachers administered by the Woodrow Wilson National Fellowship Foundation, Princeton University Campus, Princeton, New Jersey, July 2–28, 1995.

Internet: http://ucmp 1.berkeley.edu, May 1996: The Museum of Paleontology of the University of California at Berkeley and the Regents of the University of California, 1994.

Morholt, E., P. F. Brandewein, and A. Joseph, A. *Sourcebook for the Biological Sciences*, 2nd Ed., Sacramento, Calif.: California State Dept. of Education, 1967.

Science as Inquiry

Rock and Rolling Rivers

What can you interpret about geologic history from a geologic map?

Overview:

Students study geologic history and rock units by considering data on a geologic map and cross-section.

Materials:

Per lab group:
physical map of the United States
geologic map (provided)
geological timetable from Activity 2

Procedure:

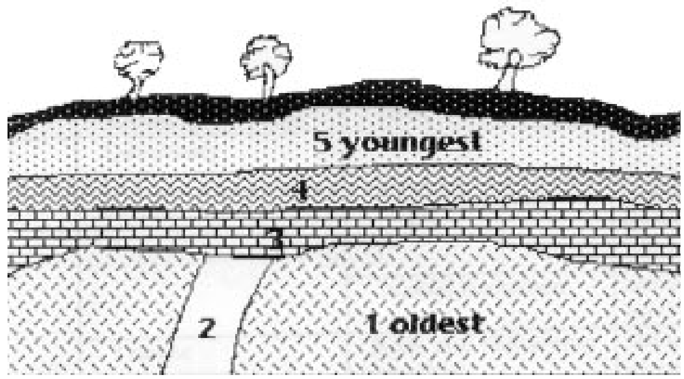
Working in pairs, students use a physical map of the United States to locate Utah, Wyo., the Rocky Mountains, the Uinta Mountains, and the Green River area. Students then use the geologic map of the Flaming Gorge and Green River to determine the relief of that area. They then use the data in the Rock Unit Data Table and their geologic timeline from Activity 2 to determine which of the rock units listed were formed during the various geologic eras and periods. The students use their understanding of the geology and relief map to determine the age and type of fossils they expect to find in the various rock units of the Flaming Gorge in Utah. You may wish to remind students to use the timelines (previously created) as a resource during this activity.

Background:

Horseshoe Canyon is one of several spectacular canyons on the Green River in Utah. The area studied in this activity is part of the Flaming Gorge National Recreation Area of Utah and Wyoming, and is located on the edge of the Uinta Mountains. Low rainfall and the resulting poor plant cover have made this an area where the layers of bedrock can easily be observed, mapped, and studied.

When Charles Darwin wrote On the Origin of Species, he and most paleontologists believed that the oldest animal fossils were the trilobites and brachiopods of the Cambrian Period, now known to be about 540 million years old. Many paleontologists believed that simpler forms of life must have existed before this but that they left no fossils. A few believed that the Cambrian fossils represented the moment of God's creation of animals, or the first deposits laid down by the biblical Flood. Darwin wrote, "the difficulty of assigning any good reason for the absence of vast piles of strata rich in fossils beneath the Cambrian system is very great," yet he expressed hope that such fossils would be found, noting that "only a small portion of the world is known with accuracy."

An important part of reading the rock record is determining the relative ages of events in the record. The law of superposition states that in a sequence of undisturbed sedimentary rocks, the oldest rocks will be at the bottom. The law of cross-cutting relationships states that an igneous rock is younger than the rocks it has intruded, or cut across. The law of included fragments states that pieces of one rock found in another rock must be older than the rock in which they are found. One example would be pebbles found in a conglomerate. The pebbles must have existed before the conglomerate formed and are, therefore, older. An unconformity is a place in the rock record where layers are missing. The missing layers may never have been deposited. More often, however, the rock layers may have been deposited and later removed due to erosion. Geologic events may occur causing the layer to resubmerge and new sedimentation may then bury the older rock unit once again. Unconformities sometimes appear to create gaps in geologic time within a specific region.



The relative ages of the rocks are given by numbers. The surface that separates layers 1 and 3 is an unconformity.

Variations:

If available, rock samples simulating each of the types described in the table could be used for study and consideration during this activity. The samples could be used for various common tests of properties of rocks (e.g., acid test).

Adapted from:

Internet: http://ucmp 1.berkeley.edu, May 1996: The Museum of Paleontology of the University of California at Berkeley and the Regents of the University of California, 1994.

Spaulding, N. E., and S. N. Namowitz, *Earth Science*, Lexington, Mass.: D. C. Heath and Company, 1994.

Era	Geologic Period	Rock Unit	Description
Cenozoic	Quaternary	Alluvium	modern surface deposits of loose sand and gravel
Mesozoic	Jurassic	Carmel Formation	limestone at base, with green and red shale at top
		Navajo Formation	cross-bedded quartzitic sandstone
	Triassic	Chinle and Shinarump Formations	Shinarump: coarse-grained sandstone, siltstone grading up into shale;
			Chinle: fine-grained sandstone
		Moenkopi Formation	siltstone with sandstone and shale
		Dinwoody Formation	shale, siltstone and sandstone
Paleozoic	Permian	Park City Formation	limestone with sandstone, shale, mudstone, and dolostone
	Pennsylvanian	Weber Sandstone	mostly calcareous sand-stone
		Morgan Formation	limestone at base, red shale and siltstone in middle, fine-grained calcareous sandstone at top
Proterozoic and Archean	Precambrian	Uinta Mountain Group	medium- to coarse-grained, dark red, quartzitic sand-stone and quartzite

Teacher Sheet

Science as Inquiry

Ruffles Aren't Ridges

How can statistical analysis help you study fossils?

Overview:

Students analyze data from a group of brachiopod fossils to determine whether the two brachiopod populations differ. They will use the data provided to speculate about the evolution of brachiopods at that location (where the fossils were allegedly found).

Materials:

Per lab group:
graph paper
colored pencils, at least two different colors

Procedure:

Students should work with at least one partner. The students will compare two populations of brachiopod fossils and determine if there is a significant difference between them. They are given data about the number of ridges on one side of the central ridge on the shells for 100 specimens (50 of each population). The students are told to decide what would be the most useful strategy for analyzing the data and prompted to consider using one or more of the following calculations: frequency, median, mode, mean. You may want to review these concepts during a pre-lab discussion including the determination and use of each derived value, however, it is important that the students consider for themselves the merits and usefulness of each method for use in this activity. The students then create data tables and graphs for each set of calculations. They should plot the data for both populations on the same graph(s) by using different colored pencils for each population of brachiopods.

The students should find that the medians for Populations 1 and 2 are 11 and 18 respectively. They would also find that these are the same values as the mode of each population. Upon graphing the data, the students will find that there is very little overlap between the plotted points for both the modes and the medians of the two populations, i.e. the modes and medians of the two populations are different. Based on this finding, the students should conclude that the two populations are distinct.

The students should consider other ways to analyze the brachiopod populations, such as measuring the dimensions of the shells, including length, width, or thickness.

The students will also consider the significance of subsequently finding 50 more brachiopod fossils at the same site where the Population 2 fossils were found, only the new fossils come from a layer of rock which is younger than the original find. Based upon the information they are given and their own statistical analysis, the students should conclude that the number of ridges on the brachiopods' shell is increasing over time. They should consider and discuss the significance of this from an evolutionary perspective in terms of what survival advantage might there be from having a greater number of shell ridges, and what might this indicate about the environmental conditions and biotic relationships of that time period.

Background:

Hands-on experience with fossils is definitely desirable in the study of geologic time and the fossil record. If actual Paleozoic fossils are not available, consider buying the plastic models that are available from most science suppliers. Some teachers consider the plastic versions over the actual samples because they show details clearly and are not easily damaged or destroyed.

Ideally, you should precede this activity with a discussion and examination by students of fossil bivalves and brachiopods. Ask students to compare the shape and structure of the two kinds of shells. In brachiopods, each valve is symmetrical on either side of a central axis. However, the two valves of a brachiopod are not symmetrical to each other. The valves of a bivalve are mirror images of each other, but the single valve is not symmetrical.

Both brachiopods and bivalves still exist today. However, the brachiopods were far more abundant during the early Paleozoic. Bivalves, in contrast, have done quite well throughout geologic time and exist today in abundance and variety.

Variations:

Molded plastic sheets with casts of two kinds of brachiopods are available from science supply houses. These can be used in this activity instead of (or in addition to) the data in the data table provided. Besides ridge number, the length, width, or height of each fossil could be determined and plotted on a variety of graphs.

You may wish to incorporate more sophisticated statistical techniques for the data analysis including standard deviation and Chi-Squared tests.

You may wish to have different lab groups determine different statistical values and compare them in a teacher-led class discussion, including the apparent usefulness of each statistic. This would be especially useful if the students do not have significant experience using these types of statistics.

Adapted from:

Illustration, Collinson, *Illinois Geological Survey*, from Brice, James C., and Harold L. Levin, Laboratory Studies in Earth History, 2nd Ed., Dubuque, Iowa: Wm. C. Brown Co. Publishers, 1977, Fig. 7-21, p. 64.

Spaulding, N. E., and S. N. Namowitz, *Earth Science*, Lexington, Mass.: D.C. Heath and Company, 1994.

Science as Inquiry

All Things in Due Time

Item:

Geologic time is divided into five eras. All of the following choices contain the name of one of those eras and a description of significant events during that time period. They are intended to be listed in the correct order beginning with the most ancient era. Which choice below is incorrect? The error could be in the order listed or in the described event(s) for that era.

A. Archean. Earth began to form by condensation of dust particles into a molten mass; early life forms existed as simple single-celled organisms without a nucleus; little or no free oxygen in the air until the end of this era.

B. Proterozoic. 2,500 million years ago (mya), Eukaryotic organisms (having hereditary material in a cell nucleus) may have first appeared; free oxygen has now accumulated in the atmosphere in significant amounts; soft-bodied animals were likely to exist during this time.

C. Paleozoic. 570 mya, first appearance of plants followed by an accelerated divergence of plant and animal phyla; fishes and invertebrates (organisms lacking an internal backbone) dominated the animal species of this time period.

D. Mesozoic. 225 mya, the “Age of Dinosaurs” or reptiles; humans (Homo sapiens) did not exist at this time.

E. Cenozoic. 65 mya, the most recent era in geologic history; the “Age of Mammals” and includes the present time. Many forms of plants and animals which existed in earlier eras have become extinct while others like turtles and many varieties of insects have survived and live today with very little change in appearance or behaviors.

Justification:

What types of evidence of the earliest life forms exists today and from what era are they from?

Answer:

C. Students should realize that plants had to exist prior to the proliferation of complex multicellular animals and that simple plant forms, like blue-green algae, contributed free oxygen to the atmosphere as a by-product of photosynthesis during the late Archean era and just prior to the Proterozoic era. Structures such as stromatolites are some of the oldest known fossils of early life and were formed by algae (plants) during the Archean era and continue to exist today in isolated locations.

Science as Inquiry

Reading the Rocks

Item:

How does knowledge and understanding of sedimentary rock formation help in determining the age of fossils and the stages of evolution?

Answer:

Students may incorrectly focus on how fossils are formed rather than on how the age of fossils and the sequencing of the stages of evolution is determined. You may wish to provide guidance in this regard when using this assessment item.

Fossil shapes were left in rocks by plants and animals that lived millions of years ago. The fossil and the rock must have been deposited at the same time in order for the fossil to be a part of the rock layer. Several methods can be used for finding and identifying the age of a rock, which also gives insight into the age of the fossil remains and evidence of the nature of life forms of that particular period or era. A fundamental concept in studying Earth's history is that in a sequence of undisturbed sedimentary rocks, the oldest rocks will be at the bottom of the sequence and the youngest will be at the top (Law of Superposition). Therefore, in general, the relative ages of fossils can be determined by which layer of sedimentary rock each fossil was found in. This allows us to determine the evolutionary sequence of certain life forms. Also, by using modern radioactive dating techniques, the actual (v. relative) age of rocks can be approximated thus providing actual ages of the fossils contained in the rock sample.

Science as Inquiry/
History and Nature of Science

A Timely Story

Item:

In some places, like the Grand Canyon in the Western U. S., we find exposed layers of rock strata, most of which are composed of sandstones or limestones that were laid down at the bottom of the shallow seas that once covered that part of North America. However, during the history of Earth, there were times when this region of land rose in elevation, the seas drained away and the sea bed became dry. During these dry periods the deposits on the surface could easily erode. Later, the land sank again, seas flooded back, and deposition forming new rock layers restarted. How might such a scenario affect the fossil record in the rocks of the Grand Canyon? How would this affect your ability to sequence the relative ages of fossils found there?

Answer:

Fossils that may have been contained in the dry exposed layers would likely be eroded away with the land. This would create a gap in the rock and fossil records because evidence from certain time periods would be missing, i.e., eroded away. However, the broad lines in the sequence of fossil evidence would still remain. You would still be able to determine the relative ages of the existing fossils and therefore determine an evolutionary sequence which would be reliable except for gaps at certain places in the sequence.

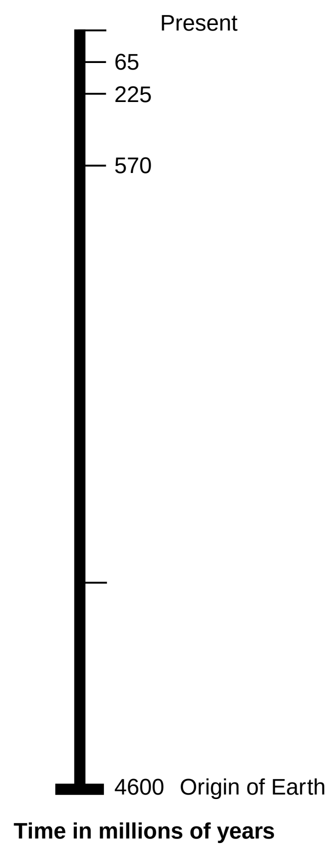
Science as Inquiry

Time on the Line

Item:

Which of the following descriptions represents the greatest amount of time?

A. Cenozoic era + Mesozoic era
B. Mesozoic era + Paleozoic era
C. Paleozoic era + Proterozoic era
D. Proterozoic era + Archean era



Justification:

Look at the geologic time line Delete which portion of the time line would represent your answer.

Answer:

D. The Archean + Proterozoic eras together comprise roughly seven-eighths of Earth's history. On the time line, this time period (together called, Precambrian) would begin at the bottom and go up more than two-thirds of the way towards the present.

History and Nature of Science

A Darwinian Dilemma

Item:

When Charles Darwin wrote On the Origin of Species, he and most paleontologists believed that the oldest animal fossils were the trilobites and brachiopods of the Cambrian Period, now known to be about 540 million years old. Many paleontologist believed that simpler forms of life must have existed before this, but that these forms of life left no fossils. A few believed that the Cambrian fossils represented the moment of God's creation of animals, or the first deposits laid down by the biblical Flood. Darwin wrote, "the difficulty of assigning any good reason for the absence of vast piles of strata rich in fossils beneath the Cambrian system is very great," yet he expressed hope that such fossils would be found, noting that "only a small portion of the world is known with accuracy."

Since Darwin's time, the fossil history of life on Earth has been pushed back to 3.5 billion years before the present. Based on what we now know today, explain why the people of Darwin's time were not able to cite evidence of life's existence prior to the beginning of the Cambrian time period.

Answer:

Evidence indicates that the Earth formed about 4.5 billion years ago. Simply to comprehend that vastness in time is no easy task, and even tougher for people of Darwin's time who were unaccustomed to considering such ancient beginnings of the Earth. In rough terms, it was only around 540 million years ago (mya) that animals evolved external skeletons, like shells, and the somewhat later animals formed internal skeletons, such as the bony elements of vertebrates. Prior to that time, the existing soft-bodied organisms were not able to easily create lasting evidence of their existence. Earlier still, the first life forms were primarily microscopic bacteria and algae, once again making the production of recognizable fossils very difficult given the technology of Darwin's time.

Yet another constraint was not knowing a fossil when you saw one. For example, the stromatolites were not immediately recognized as direct evidence of plant-life (blue-green algae) from as long as 3 billion years ago (3000 million). The invention and refinement of radiometric dating techniques has also greatly contributed to our knowledge of the Earth's history, and this modern advantage is continually being improved upon.

Of course, a simple but important consideration is that many of the world's richest deposits of fossils had not yet been discovered. Moreover, the most suitable places for fossilization are in seas and lakes where sedimentary deposits are slowly accumulating. This makes it somewhat extraordinary that many land-living creatures would ever be fossilized since they would have to have either fallen or been taken into the water in the first place. Finally, of the fossils ever in existence, only a tiny portion happen to lie in the rocks that outcrop on the surface of the ground today; and of these few, most are eroded away and destroyed before fossil hunters of any human era could discover them.

Consumables

Item	Quantity (per lab group)	Activity
colored pencils, different colors	2	4
colored pencils, different colors	5	1
bone fragments from an owl pellet (optional),	10–12	2*
clay, dry powdery	50–100 mL	2*
geological timetable from Activity 2	—	3
graph paper	—	4
gravel, coarse	50–100 mL	2*
humus	50–100 mL	2*
jar (large—pickle or mayonnaise jar)	1	2*
paper, (adding machine tape)	at least 1-meter long strip	1
rocks, small, (0.5–1.0 mm dia.)	50–100 mL	2*
sand, fine	50–100 mL	2*
shell fragments of var. sizes (approx. 1 mm dia.)	50–100 mL	2*

Nonconsumables

Item	Quantity (per lab group)	Activity
physical map of the United States	1 (per class)	3

*indicates alternative or additional activity

Key to activities:
1. A Journey Through Time
2. A Traditional Layer Cake
3. Rock and Rolling Rivers
4. Ruffles Aren't Ridges

Activity Sources

Attenborough, David, *Life on Earth*, Boston: Little, Brown and Company, 1979.

Dombrowski, J., and A. Sullivan, *Evolution—A Context for Biology*, The Howard Hughes Medical Institute for High School Teachers administered by the Woodrow Wilson National Fellowship Foundation, Princeton University Campus, Princeton, New Jersey, July 2–28, 1995.

Internet: http://ucmp 1.berkeley.edu, May 1996: The Museum of Paleontology of the University of California at Berkeley and the Regents of the University of California, 1994.

Morholt, E., P. F. Brandewein, and A. Joseph, *A Sourcebook for the Biological Sciences*, 2nd Ed., Sacramento, Calif.: California State Dept. of Education, 1967.

(continued)

Spaulding, N. E., S. N. Namowitz, *Earth Science,* Lexington, Mass.: D. C. Heath and Company, 1994.
Zihlman, Adrienne L., *The Human Evolution Coloring Book,* New York: Harper & Row, Publishers, Inc., 1982.
Illustration, Collinson, Illinois Geological Survey, from Brice, James C., and Harold L. Levin, *Laboratory Studies in Earth History,* 2nd Ed., Dubuque, Iowa: Wm. C. Brown Co. Publishers, 1977, Fig. 7-21, p. 64.