Teaching Paleontology in the National Parks and Monuments

A Curriculum Guide for Teachers of the Fourth, Fifth and Sixth Grade Levels

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Introduction

Teaching Paleontology in the National Parks and Monuments is a fossil education program designed by National Park Service staff for use in the classroom and in the Parks.

Teaching Paleontology consists of three units for fourth, fifth, and sixth grades. The units are designed as building blocks for increasing the student's knowledge and understanding of fossils. The program focuses on the different types of fossil formation, how we use the information from fossils to put together a picture of the past, the earth forces that have contributed to the changing life and climate we find reflected in the fossil record and the role the National Park Service plays in fossil protection. The three units are:

1. Fourth Grade; What Are Fossils
2. Fifth Grade; Putting Together the Pieces
3. Sixth Grade; Our Changing Earth

Each unit includes goals and objectives, a teacher's introduction to the subject matter covered in the unit, sources for further information, vocabulary and concepts, classroom activities and outdoor activities. While the units are designed to be used as building blocks from fourth grade through sixth grade, each unit can stand on its own.

Each activity includes objectives, materials list and background information so it can be conducted without having to review the relevant material in the **Teacher's Introduction**. Any handouts associated with an activity are on pages to be removed for photocopying. You may choose to do some or all of the activities in each unit. An appendix is included at the end of Teaching Paleontology with concepts and objectives for each activity so that you can better meet your class needs. If your class is limited by time, you may choose to split the group into teams, with each team completing an activity and then reporting back to the rest of the class about their findings.

While Teaching Paleontology contains many activities designed to give students a hands-on experience, nothing can replace a visit to a fossil site. Also, each unit has a slide show to reinforce the principles. The script has been included to provide further information for your unit. You can arrange a visit to a National Park site or a showing of the slide show by contacting the park nearest your school. A list of NPS fossil sites, including phone numbers, is found in the index.

The National Park Service (NPS) was created in 1916 and since that time it has been preserving, protecting and managing the cultural, natural, historical and recreational areas of the National Park system. Many different types of areas make up the Park System. In addition to National Parks, the System contains natural preserves, historic sites, battlefields, seashores and lakeshores, national rivers, parkways and recreation areas. The System also contains national monuments, including natural preserves, historic fortifications, fossil remains, prehistoric ruins, and memorials.

As diverse as they are, these places share a common element; they are all unique expressions of our national heritage, preserved and protected for the future by the National Park Service. Since preservation and protection is the goal of the National Park Service, it is an ideal agency to take care of the important fossil areas in our country. Eight areas have been set aside as part of the Park system specifically to preserve fossils. However, there are more than 100 National Park areas with fossil resources. An example is Grand Canyon National Park. This park was created because of the scenic beauty and natural history of the canyon itself. However, the different rock layers of the canyon yield a variety of fossils dating back to 3 billion years ago. So, while the Grand Canyon is not thought of as a "Fossil Park", fossils are an important part of the story of the Grand Canyon. The fossils are protected by the National Park Service along with all the other aspects of the Grand Canyon, like the plants, animals, the Colorado River and the entire ecosystem.

In addition to preservation and protection, the NPS Mission has an additional element; to provide for the enjoyment of the visitor. At times this dual mission can prove to be contradictory. It has been said that the National Parks are being "loved to death", with the tremendous increase in visitation undermining the very values that the parks were created to preserve.

Education has been shown to be a vehicle for meeting this dual mandate, and that is the underlying purpose of this curriculum. By teaching the public about these fossil parks that are part of our shared heritage, the NPS can instill a sense of appreciation for the parks. This can lead to a sense of protection and so the dual mandate is met; visitors enjoy the resource and help to protect it. We hope you will use this curriculum guide with this spirit in mind, and help to convey the sense of wonder and pride that our National Parks inspire.

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Fascinating Fossils

Teacher's Introduction

Fossils are fascinating. To hold a fossil in your hand and realize that it once was part of a living organism, one that existed millions of years ago, is awe-inspiring. Fossils don't represent the same time periods in the earth's history, nor are they formed in the same circumstances. This unit is designed to put the several types of fossils and the geologic times they represent into a framework or perspective.

For a fossil to form there has to be a specific sequence of events. Rapid and complete burial is a must in all types of fossil formation. This ensures that bacteria and fungi will not begin attacking and decaying the organism. A lack of oxygen in the burial environment is also significant because it limits the rate of decay of organic materials.

Most fossils are found in sedimentary rocks. These types of rocks are formed when many layers of silt, volcanic ash or precipitates build up on the bottom of lakes or seas. Because of the unique chain of events that are necessary for fossil formation to occur, very few organisms turn into fossils. The fossils that we find represent only a small fraction of the life that has existed on earth and are only glimpses into the past. We have to use scientific reasoning and imagination to see a more complete picture.

The main types of fossil formation are:

Petrification (Permineralization): This type of fossilization occurs when certain parts of an organism are saturated with a mineral-rich solution. The solution (water that has dissolved minerals in it) penetrates into the organism and gradually the minerals begin to fill in the cell walls of the organism. Highly porous materials such as bone and wood are often permineralized. Examples of petrified fossils are the petrified wood found at Petrified Forest National Park and dinosaur bones found at Dinosaur National Monument.

Carbonization or Imprint Fossils: In this process the organism becomes buried in layers of sediment. As the layers of sediment build up, the sediment becomes pressurized from the weight, squeezing out water and gasses from the organism. Eventually the organism disintegrates except for the carbon. This carbon leaves an imprint or residue. Examples of carbon or imprint fossils are found at Florissant Fossil Beds National Monument and Fossil Butte National Monument.

Molds and Casts: Molds are fossilized replicas of the structure of an organism. The best examples of this type of fossil are clams or brachiopods. When a clam dies, over time the soft parts of the animal decay. The shell is left empty and this becomes filled with sediment. Eventually the shell dissolves away, but the sediments have hardened and remain as a fossil. An external mold shows the outer surface of the shell and an internal mold shows the inside surface.

The difference in casts and molds lies in what happens when the shell dissolves away. If the shell dissolves before its empty cavity is filled it leaves a void in the surrounding rock, which then becomes filled with sediment. The “cast” fossil that forms in the cavity shows signs of the outer shell features.

Trace Fossils: Trace fossils are the preserved remains or signs of animals left behind as they went about their lives. They include footprints, or tracks, burrows, nests, eggs and feces.

Geologic Time

Geologic time is very difficult to comprehend, especially for children who are used to thinking of time in terms of minutes and hours and to whom summer vacation, which lies only months away, seems an eternity. The time line activities included in this unit can make geologic time units more real to them and put time into a perspective they can understand. Before the mid 1900's, it was impossible for even scientists to comprehend the vast amounts of time involved in our earth's history. That was because the only method for dating different rock layers was relative dating. This dating method is based on the assumption that rock layers build up in a chronological sequence, with the younger rock layers lying on top of older layers. Thus, fossils found in two different layers of rocks could be dated relative to one another, with the older fossils found in the lower layer. However there was no way to tell how old either fossil actually was.

Index fossils are fossils that are indicators of a particular time in the earth's history. Plants and animals that evolved quickly and flourished for a short period of time before becoming extinct are indicator species. If they became fossilized and occur in a particular rock formation, they are an indication of the relative age of the rock. While these index fossils can be accurately dated with radiometric dating, they are also very useful in relative dating. In the middle part of this century a new technique, called radiometric dating was developed.

This method is based on the observation that radioactive elements, radioisotopes, break down into other elements at a fixed rate. By measuring the amount of radioactive elements in a rock, figuring out what proportion of radioisotopes have broken down into other elements and using the rate at which this breakdown is known to occur, scientists can estimate the approximate age of a layer of rocks.
When scientists began to discover the vast amounts of time involved in the earth's history, it became necessary for them to develop a means for dividing time into more manageable periods of time. A system was then created that divided stages of time based upon the evolving changes in life on the planet. The chart provided gives the breakdown of time and life forms associated with different eras and epochs and the activity "When in the World" lets students obtain a hands-on sense of geologic time.

Fossils and the National Park Service

We can learn about ancient life only if that life is preserved as a fossil. That process is very rare, so only small portions of fossilized life are here today as clues to the past. Just because something has been fossilized doesn't mean it can last forever. When fossils are exposed to the elements, they will weather away just like any other rock. Also, if they are dug up and removed from the rocks around them, the context is lost, with all the clues and information that could be gained from that context. Thus, it is very important, if we are to learn from fossils, that they be protected.

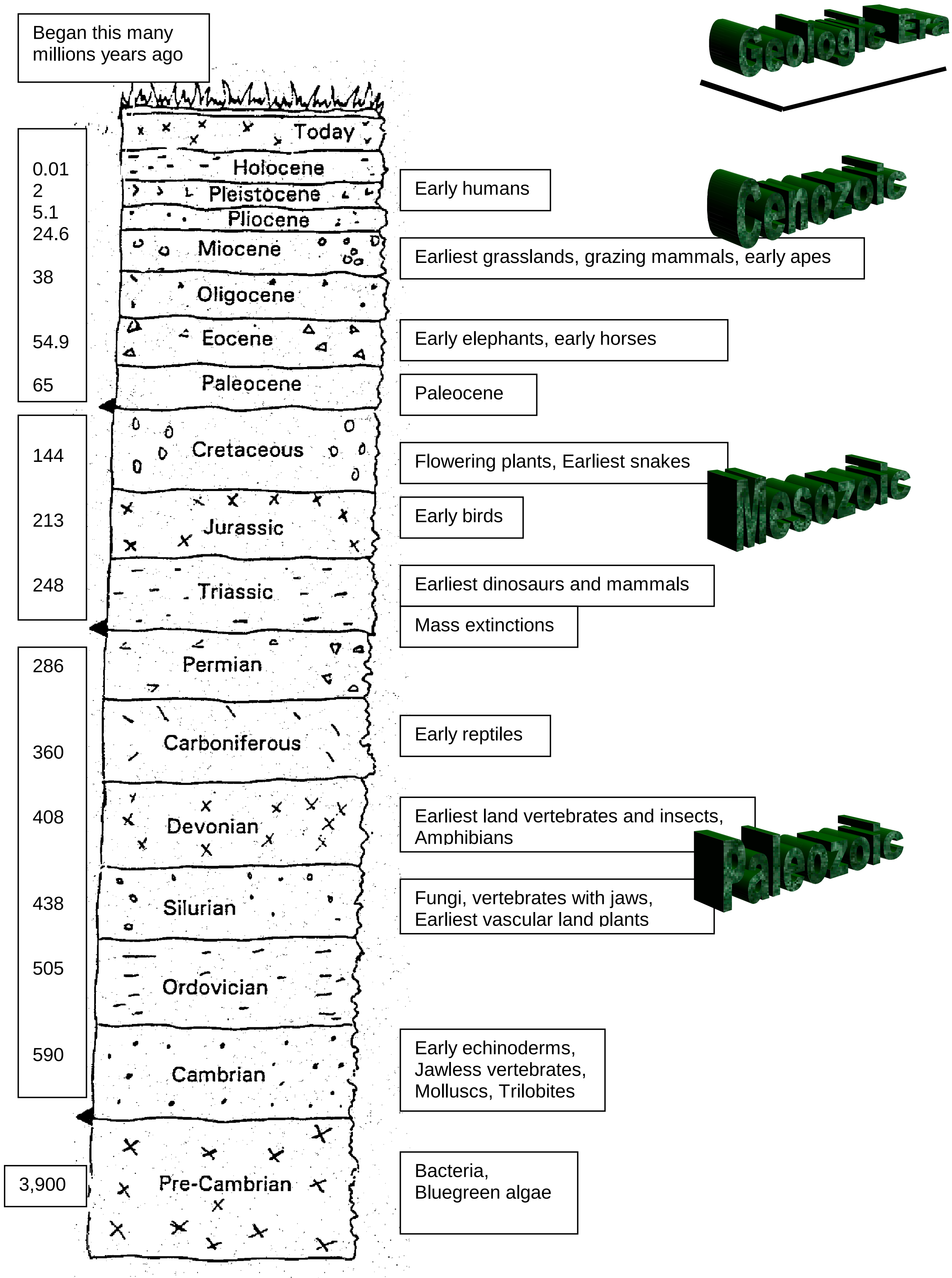
Since the job of the National Park Service is to preserve and protect our national treasures, it is an ideal agency to take care of the important fossil areas in our country. The National Park Service (NPS) was created in 1916 and since that time it has been preserving, protecting and managing the cultural, natural, historical and recreational areas of the NPS system. Many different types of areas make up the Park System. In addition to National Parks, the System contains natural preserves, historic sites, battlefields, seashores and lakeshores, national rivers, parkways and recreation areas. The System also contains national monuments, including natural preserves, fossils, historic fortifications, prehistoric ruins, and memorials. As diverse as they are, these places share a common element; they are all unique expressions of our national heritage, preserved and protected for the future by the management of the National Park Service.

Eight areas have been set aside as part of the Park System specifically to preserve the fossils found there; however, there are more than 100 National Park System areas with fossil resources. An example is Grand Canyon National Park. This park was created because of the scenic beauty and natural history of the Canyon itself. However, the different rock layers of the canyon, some dating to 2 billion years old, yield a variety of fossils. So, while the Grand Canyon is not thought of as a “Fossil Park”, fossils are an important part of the story of the Grand Canyon. The fossils are protected by the National Park Service along with all the other aspects of the Grand Canyon, like the plants, animals, the Colorado River and the entire ecosystem.

As an introduction to the eight fossil parks, students are asked to research these areas as an activity. Names and addresses are provided in the activity “Our Fossils”. Also, a copy of the Organic Act (of 1916), the founding legislation of the National Park Service is provided so that the students can better understand the important mission of the National Park Service.

Organic Act of 1916

The National Park Service shall promote and regulate the use of Federal Areas known as national parks, monuments and reserves. The purpose is to preserve the scenery, natural and historical objects, and wildlife, and to provide for the future enjoyment of these areas in such a way that will leave them unimpaired for the enjoyment of future generations (August 25, 1916).



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Unit Goals and Objectives

Goal: Students will become familiar with different types of fossils and their formation.
Objectives: Students will identify three fossil types.
Students will name a NPS area associated with each fossil type.
Students will describe how each type of fossil forms.
Goal: Students will understand the purpose of the National Park Service.
Objectives: Students will list two reasons why National Parks are important.
Goal: Students will gain an understanding of geologic time.
Objectives: Students will compare and contrast units of geologic time with time units conceivable to them.
Students will be able to list three significant events in the earth's history.
Students will name a dating method.

Vocabulary

Mineral: A substance found in the earth that always has the same properties. These properties include color, hardness, shininess, and the way the mineral breaks or splits.
Solution: A substance dissolved in another substance, in this case water.
Sediment: Any substance that settles out of water.
Element: A substance made up of only one kind of atom.
Carbon: An element. Atoms of carbon are the building blocks of living cells.
Petrify: A process that replaces living materials with mineral matter.
Paleontologist: A scientist that studies ancient life through fossils.
Paleozoic: A geologic era that is the time of ancient life. The Paleozoic era is divided into seven periods designated by inundations of seas.
Mesozoic: This geologic era represents the time of "Middle" life.
Cenozoic: The "Age of Mammals", this geologic era is the most recent.
Relative Dating: A method of dating rock layers by their relationships or proximity to each other.
Radiometric Dating: A dating method that measures the amount of radioactive decay that has taken place in the rocks being studied.

Sources for further Information

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Prehistoric Life, Steve Parker, See and Explore Library, Darling
Kindersley Inc. London, N.Y., Stuttgart.

Fossils. A Golden Guide, Rhodes, Zim and Shaffer, Golden Press, N.Y. 1962.
ISBN 0-3-7-24411 –3

The Fossil Factory, Niles, Douglas and Gregory Eldredge, Addison
Wesley Publishing Co, Inc. New York. ISBN 0-201-18599-7

Understanding and Collecting Rocks and Fossils, Martyn Bramwell, 1983,
Usborne Publishing Ltd. Saffron Hill, London ECIN 8RT England. ISBN
0-86020-765X

Audubon Society Field Guide to North American Fossils, Alfred A. Knopf
Publishing. ISBN 0-394-52412-8

A Field Guide to Dinosaurs Coloring Book, Houghton Mifflin Co. Boston. This book
has excellent illustrations, with fossils from other
time periods in addition to the dinosaurs. ISBN 0-395-49323-4

Fossils. A New True Book, A New True Book, Childrens Press, Chicago;
Regensteiner Pub. Enterprises Inc. ISBN 0-516-41678-2

The Usborne Book of Prehistoric Facts, EDC Publishing; contains
records, lists, comparisons. ISBN 0-86020-9733

Fossils, Eyewitness Handbooks; A visual guide to more than 500 species of
fossils from around the world, Dorling Kindserley Inc. ISBN 1 -56458-071 –7

Prehistoric Animals- A fun to learn activity book; Watermill Press. ISBN
08167-0426-0

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Classroom Activities

Classroom Activity 1
Grow A Crystal

Objectives: Students will be able to describe how petrified fossils are formed. They will explain what a solution is and will observe what happens when an object is surrounded by a mineral solution.

Background: While it is impossible to duplicate the petrification process this activity will help students see how an organism becomes petrified. Petrified and replaced fossils are formed when a dead organism, or part of one, is surrounded by a saturated solution of dissolved minerals. Solutions are formed when a substance, in this case a mineral, is dissolved in water. A saturated solution is achieved when the liquid contains so much dissolved substance that no more can be dissolved at the given temperature. The petrification process takes place as the water evaporates or changes in concentration and the minerals are deposited in the cells of the organism.

Materials:

Small pan	Water
Heat source	Walnut shells (2 to 4 halves)
Plastic container (two cup capacity)	Spoon

4 ounces Alum (aluminum ammonium sulfate). This can be purchased from a drugstore. **Note:** Alum isn't toxic but should still be handled carefully.

Procedure:

1.Review the concepts of solution and saturated liquids.
2.Put about one half cup of water in the pan and stir in about 2 ounces of alum (about 6 tablespoons).
3.Heat the solution but don't let it boil.
4.Remove the pan from the heat and stir in more alum until no more will dissolve. When no more will dissolve, you will start to see some of the alum on the bottom of the pan. At this point you have a saturated solution.
5.Pour the saturated solution into the plastic container. Place the halves of the walnut shells into the container, open side up. Set the container in a draft free place where it won't be disturbed.

Follow Up:

After a week or so (the time span will depend on the humidity of your classroom and the relative saturation point that was reached in step 4) have the students observe the shells. They should observe crystals of alum that have formed in the empty space of the interior of the shell. Point out that this is what occurs when the cell spaces of an organism are filled in, or permineralized, in the fossilization process. In this manner of fossilization, it is the hard parts of an organism that are fossilized bones or teeth in animals and the woody part of plants. The crystals formed because there was room for them to grow in the open spaces of the walnut shell. When minerals are deposited in the cells of bone or wood the spaces are usually too small for this to occur. But, if there is a large enough space in the fossil, crystals are able to form and can be observed. Look at the fossils that your class has available to them or see when they visit the National Park. Can they observe this phenomena?

Some of the biggest petrified fossils in the world are found at Florissant Fossil Beds National Monument in Colorado. Giant sequoia trees that grew there 35 million years ago became petrified when the bases were surrounded by mudflows from a nearby volcano. The flows hardened into a rock called tuft that protected the trunks and kept them from decaying. Over time, water penetrated into the tuft, dissolved some of the minerals in it, mostly silica from the volcanic rock, and this mineral rich solution penetrated into the trunks of the trees and petrified them. Where there were cracks in the wood, veins of quartz can be seen and if there was enough space for crystals to grow, you can find quartz crystals that look very similar to the crystals you grew in the activity. If you visit Florissant Fossil Beds, you can see the trunks still standing in place, some of them nearly 12 feet tall. Are redwood trees found in Colorado today? Where do they grow and what is the climate like there?

Classroom Activity 2

Make a Fossil

Background: This activity gives students a better understanding of how two other types of fossil are formed; impression fossils and cast fossils.
impression Fossils (Carbonization): In this process the organism becomes buried in layers of sediment. As the layers build up they become heavier, pressing down on the organism and squeezing out water and gasses. Eventually the organism disintegrates but the carbon remains behind, leaving an imprint or residue. Carbon is a major building block for all living cells, and all living things.

Molds and Casts: Molds are fossilized replicas of the internal structure of an organism. The best examples of this type of fossil are clams or brachiopods. When a clam dies, over time the soft parts of the animal decay. The shell is left empty and this becomes filled with sediment. Eventually the shell dissolves away, but the sediments have hardened and remain as a fossil. An external mold shows the outer surface of the shell and an internal mold shows the inside surface.

The difference in casts and molds lies in what happens when the shell dissolves away. If the shell dissolves before its empty cavity is filled, it leaves a void in the surrounding rock, which then becomes filled with sediment. The “cast” fossil that forms in the cavity shows signs of the outer shell features.

Trace Fossils: Trace fossils are the preserved remains or signs of animals left behind as they went about their lives. They include footprints, or tracks, burrows nests, eggs and shells and feces.

Materials for Part one:
empty cardboard milk container 1 quart size (or plastic)
shell or a plastic Easter egg one half per student or team
petroleum jelly
plaster of paris and water
container for mixing the plaster of paris and water
food coloring

Procedure: For each team or student have them:

1. Cut off the milk carton so it’s approximately 5 inches tall.
2. Grease with petroleum jelly the interior of the milk carton, the half of the Easter egg or other object that they wish to “fossilize”; a stick, leaf, or even their hand
3. Mix up3 cups of plaster of paris and pour it into the carton.
4. Place the half of the Easter egg so it is sitting upright in the plaster, forming a dry well
5. Press in any other object that is to be fossilized.
6. Let the mixture harden, then cover the surface of the first layer with petroleum jelly.
7. Mix a second batch of plaster of parts, but this time add food coloring to tint the mix. Pour it on top of the hardened 1st

batch.
8. After the mixture has hardened over night, remove the plaster block from the carton. You now have a piece of “fossil bearing rock”.

Materials for part two:
paint brush
spoon
dull knife
wood block for hammering

Procedure: Students will excavate their fossils, using the knife and spoon to chisel, and paint brush to brush dust from the specimens. When finished, they will have a cast fossil, an impression fossil and a trace fossil.

Follow-up: Discuss the three types of fossils they have made. What are the conditions necessary for fossils to form (rapid and complete burial). What would have happened to the fossils if the top layer had not been added? What if the things that were fossilized had been dead organisms? How did they excavate the fossils? Were any of the fossils destroyed when they uncovered them?

Use **Classroom Activity 4, Our Fossils** as a follow-up to this experiment to name fossil sites where the different types of fossils are found.

Classroom Activity 3
When in the World

Objective: Students will compare and contrast units of geologic time with spatial units conceivable to them. They will list three events that were significant in the natural history of the earth.

Background: Students will use math skills to construct a time line. This activity will give them perspective on the span of time associated with the earth’s history and some of the important events in the evolution of life. Preview the activity with a discussion of dating methods from the “Teacher’s Introduction”.

Materials:
list of measurements
measuring tape
wooden stakes or wire flags for outdoor time line

Procedure: Students will use table of measurements provided to make a time line. For the indoor time line, they can mark the significant events on computer paper. For the outdoor-time line, they can mark the significant events with flags or wooden stakes.

Follow Up: Have the students find objects or pictures to represent the important events on the time line. When these are compiled, have the students discuss these events and what they mean. Topics for discussion include:

Life on Earth Begins: Scientists believe that the first life forms on the planet were very SIMPLE life forms; algae, bacteria, fungi. What do algae need to live? How about bacteria and fungi? What do algae produce as a by-product? As the first plants on earth, algae were extremely important in producing oxygen.

1st Fossils: Discuss the special conditions necessary for fossils to form (rapid and complete burial before decomposition). Since those conditions tend to be rare, are fossils a good representation of all of the life forms that existed at that time? Why not?

1st Amphibians: What is an amphibian? Amphibians have been on the planet for a very long time but have been rapidly disappearing in recent years. Why? What could this mean? Why does it matter to us?

Swamp Forests: Why are these swamps important to us? They formed the coal and fossil fuels that are major sources of energy for us. What kind of forces transformed these organic materials into coal and oil? This shows us that fossil fuels are limited and take a very long time to form.

Age Of Dinosaurs: A look at the long portion of the time line that represents the Age of Dinosaurs shows you that dinosaurs were very successful as a life form. What do you think could have caused their demise? New discoveries and research are indicating that they may have been very active and quick, and had fairly elaborate social interaction with another. How does this compare with the ways people used to view dinosaurs?

Age Of Mammals: What does the term Age of" mean? Did mammals exist before this point? What is a mammal? What are the characteristics that make mammals different from dinosaurs? What differences between mammals and dinosaurs might have helped mammals survive while the dinosaurs became extinct?

1st Humans: Look at the sign representing today. Compare the "Age of Humans" to the Age of Dinosaurs. What makes humans unique? At the time of the first humans their brains were only half the size they are now but they were still much bigger than the brains of most other animals. Also, humans have opposable thumbs, allowing them to grasp. Have the students tie their shoes or write without their thumbs to see how important this development is. Talk about all the scientific discoveries/inventions that have been made in the last two hundred years. How have those discoveries changed our lives? Changed the lives of other species of plants and animals? What is "progress"? Is it always beneficial to us and/or the living beings we share the planet with?

<u>When in the World: Measurements</u>

(length from present)

INDOOR	OUTDOOR	YEARS AGO *	EVENTS
38 feet	45.7 meters	4.57 billion	Earth begins
29 feet	35 meters	3.5 billion	Life begins
28.25 feet	34 meters	3.4 billion	First fossils form
3.75 feet	4.5 meters	450 million	First primitive fish
41 inches	4.1 meters	410 million	Earliest land plants
30 inches	3 meters	300 million	Early amphibians Swamp forests
29 inches	2.9 meters	290 million	First reptiles
24.8 inches	248 centimeters	248 million	Beginning of Age of Dinosaurs
16 inches	160 centimeters	160 million	Early birds (Archaeopteryx)
13 inches	130 centimeters	130 million	Flowering plants develop
6.5 inches	65 centimeters	65 million	Dinosaurs extinct Age of Mammals begins
5 inches	50 centimeters	50 million	Mammals/birds abundant
.2 inch	2 centimeters	2 million	First humans
.15 inch	1.5 centimeters	1.5 million	Ice Age begins
.0001 inch	.0002 cms	220 (1776)	United States created

Scale: Indoor: 1/10 inch = 1 million yrs Outdoor: 1cm = 1 million yrs

* ”Years Ago” are approximate and based on fossil evidence

Classroom Activity 4
Our Fossils

Background: The National Park Service was established in 1916 in order to preserve and protect the natural and cultural treasures of the country. Read or pass out a copy of the Organic Act. The job of preservation and protection makes the NPS unique from other land management agencies.

Procedure: Locate each of the Fossil NPS areas on a map. Have teams research the sites by contacting the parks. Ask them to describe the type of fossils found at their site, how the fossils were formed, the animals or plants that are found as fossils, the ancient environment, and the present environment of their site.

Agate Fossil Beds National Monument P.O. Box 427	Fossil Butte National Monument P.O. Box 592 Kemmerer, WY 83101

Gering, NE 69341 (308) 436-4340	(303) 877-4455
Badlands National Park P.O. Box 6 Interior, SD 57750 (605) 433-5361	Hagerman Fossil Beds National Monument P.O. Box 570 Hagerman, ID 83332 (208) 733-8398
Dinosaur National Monument P.O. Box 210 Dinosaur, CO 81610 (303) 374-3000	John Day Fossil Beds National Monument 420 W. Main St. John Day, OR 97845 (503) 575-0721
Florissant Fossil Beds National Monument P.O. Box 185 Florissant, CO 80816 (719) 748-3253	Petrified National Forest Park Petrified Forest, AZ 86028 (602) 524-6228

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Outdoor Activities
Activity 1
How We Perceive Time

Background: Let's look at how we perceive time. One way to perceive it is to measure it. We humans have come up with many different ways to designate different periods of time: milliseconds, seconds, minutes, hours, days, weeks, years, decades, millennia. But these are just arbitrary units, chosen to represent periods of time that fit into our framework, our lifetimes. This exercise will help students to widen their perceptions of the passage of time and enable them to better conceive of the passing of geologic time.

Materials: A copy of the exercise to read to the students.

Procedure: Have everyone close their eyes. Ask them to remain perfectly still but open their eyes when they think a minute has passed.

Now, choose someone to be "it" and have the group play a game of tag, stopping when they think a minute is up. Is everyone's sense of time exactly the same? Are there circumstances when time seems to pass more quickly than at other times? What about when you are waiting for someone? During the last half-hour of the school day? When you are having fun? When you are bored?

How do you think time might pass for other animals? For a hummingbird? For a turtle? For a fly? How about a tree or a rock?

Have everyone stand quietly with arms outstretched, eyes closed. Now, imagine that you are all pine trees. Your head and arms are the tree's branches and your legs are its roots. Your branches are warmed by the sun. You can feel the warmth pass from your hands slowly up your arms, to your shoulders, into your trunk, and down into your roots. Your roots are cold and damp. As water is absorbed by your feet, coolness slowly passes up your legs to your trunk. The water slowly warms as it spreads out to your branches in the sun. You've grown for 300 years, standing in the sun and snow, breeze and gale. How do you experience time? What about the rocks, millions of years old, that the pine tree's roots are growing around? If they were able to experience the passing of time, what would a minute seem like to them?

Outdoor Activity 2
The Ancient Treasures Hunt

Objectives: This activity will give the students an idea of the variety of fossils that are protected by the National Park Service. It combines math and compass skills with fun. The most enjoyable part of this game is that everyone is a winner. Even if a team doesn't reach the designated goal, they are bound to find something of interest in the area that they reach.

Background: Give the students a brief introduction to compass usage. The red portion of the needle points north because it has been magnetized and is drawn to the magnetic pole.

Materials: For each group of students: List of measurements Compass Measuring tape A treasure. This can be some object that your students will find interesting, to be placed at the end of the trail.

Procedure: Before the activity begins, measure off the following distances: From the starting point go south 200 feet, then west 109 feet. Place a sign or marker at the starting point and some interesting object at the end of the trail.

When you are ready to start the activity, divide the students into teams of 6 and pass out the instructions and materials.

There are three sets of clues provided. Each group will start at the same point and end at the same point, but the teams will reach the goal by different routes. These different sets of clues ensure that each team will have to find their own route rather than following another group that is doing all the work.

Ancient Treasures Hunt Directions Set One:
Split up into groups of 6 students. Two students read the clues and do the math. Two hold the measuring tape. Two use the compass to find directions. Follow the clues to find a hidden treasure. When you reach the mystery item, leave it there for the next group to discover.

Clues:
1. The fossil of a fish, a gar, that is 5 feet long, was discovered at Fossil Butte National Monument, in Wyoming. Go south for three gar lengths.

2. Fossil remains of mesohippus are found at Badlands National Park in South Dakota. Mesohippus was an ancestral horse. It had three toes instead of one (hoof). Continue south the number of mesohippus toes on a foot times one yard.

3. At Florissant Fossil Beds National Monument in Colorado you can see the petrified remains of redwood trees that grew 35 million years ago. One petrified stump measures 12 feet tall and 38 feet in circumference (the distance around). Continue south for the length of the circumference of a redwood tree.

4. Daemonelix, Devil's corkscrews, are trace fossils, the fossilized burrows of a ground burrowing beaver, Paleocastor. Some daemonelix are nearly 6 feet tall. They are found at Agate Fossil Beds National Monument in Nebraska. Go west 4 daemonelix lengths.

5. The sabertooth cat was a fierce predator that was found in John Day Fossil Beds National Monument in Oregon. These animals had canine teeth nearly 6 inches long. Continue west for 30 fangs.

6. In Dinosaur National Monument in Colorado are found the fossil remains of apatosaurus. It got its name, which means deceptive lizard, because of its unbelievable size. Adults were 70 feet long from nose to tail. Go west 1 apatosaurus length.

7. Phytosaurus were crocodile-like reptiles that lived 220 million years ago in what is now the Petrified Forest National Park in Arizona. The average length of a phytosaur was 17 feet. Go south for 4 phytosaurs.

8. At Hagerman Fossil Beds National Monument in Idaho are found the fossil remains of a Pronghorn antelope that lived there nearly 3.4 million year sago. Modern pronghorns are the fastest land animal and can run at nearly 70 miles an hour. Go south 70 feet. Do you see anything special? Is it a fossil?

Ancient Treasures Hunt Directions Set Two:
Split up into groups of 6 students. Two students read the clues and do the math to figure them out. Two students hold the measuring tape. Two students use the compass to determine direction. Follow the clues to find a hidden treasure. When you reach the mystery item, leave it where you find it for the next group to discover.

Clues:
1. The sabertooth cat was a fierce predator that was found in John Day Fossil Beds National Monument in Oregon. These animals had canine teeth nearly 6 inches long. Go west for 30 fangs.

2. At Florissant Fossil Beds National Monument in Colorado you can see the petrified remains of redwood trees that grew there 35 million years ago. One petrified stump measures 12 feet tall and 38 feet in circumference (the distance around). Go south for the length of the circumference of a redwood tree.

3. The fossil of a fish, a gar, that is 5 feet long was discovered at Fossil Butte National Monument, in Wyoming. Go south for 3 gar lengths.

4. Fossil remains of mesohippus are found at Badlands National Park in South Dakota. Mesohippus was an ancestral horse. It had three toes instead of one (hoof). Continue south the number of mesohippus toes on a foot times 1 yard.

5. Phytosaurs were crocodile-like reptiles that lived 220 million years ago in what is now the Petrified Forest National Park in Arizona. The average length of a phytosaur was 17 feet. Go south for 4 phytosaurs.

6. Daemonelix, Devil's corkscrews, are the fossilized burrows of a ground burrowing beaver, Paleocastor. Some daemonelix are nearly 6 feet tall. They are found at Agate Fossil Beds National Monument in Nebraska. Go west 4 daemonelix lengths.

7. In Dinosaur National Monument in Colorado are found the fossil remains of apatosaurus. It got its name, which means deceptive lizard, because of its unbelievable size. Adults were 70 feet long from nose to tail. Go west 1 apatosaurus length.

8. At Hagerman Fossil Beds National Monument in Idaho are found the fossil remains of a Pronghorn antelope that lived there nearly 3.4 million years ago. Modern pronghorns are the fastest land animal and can run at nearly 70 miles per hour. Go south for 70 feet. Do you see anything special? Is it a fossil?

Ancient Treasures Hunt Directions Set Three:
Split up into groups of 6 students. Two students will read the clues and do the math to figure them out. Two students will hold the measuring tape. Two students will use the compass to determine direction. Follow the clues to find a hidden treasure. When you reach the mystery item, leave it where you find it for the next group to discover.

Clues:
1. The sabertooth cat was a fierce predator that was found in John Day Fossil Beds National Monument in Oregon. These animals had canine teeth nearly 6 inches long. Go west for 30 fangs.

2. Daemonelix, Devil's corkscrews, are the fossilized burrows of a ground burrowing beaver, Paleocastor. Some daemonelix are nearly 6 feet tall. They are found at Agate Fossil Beds National Monument in Nebraska. Go west 4 daemonelix lengths.

3. At Hagerman Fossil Beds National Monument in Idaho are found the fossil remains of a Pronghorn antelope that lived there nearly 3.4 million years ago. Modern pronghorns are the fastest land animal and can run at nearly 70 miles per hour. Go south for 70 feet.

4. At Florissant Fossil Beds National Monument in Colorado you can see the petrified remains of redwood trees that grew there 35 million years ago. One

petrified stump measures 12 feet tall and 38 feet in circumference (the distance around). Go south for the length of the circumference of a redwood tree.

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8. In Dinosaur National Monument in Colorado are found the fossil remains of apatosaurus. It got its name, which means deceptive lizard, because of its unbelievable size. Adults were 70 feet long from nose to tail. Go west 1 apatosaurus length. Do you see anything special? Is it a fossil?

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Slide Show Script

1. Title Slide: This slide show is made possible through the ongoing efforts of the National Park Service. The NPS is responsible for preserving some of the very special places in our country. Some of those places are beautiful spots in nature and important wildlife habitat. Others are places of historic value, or even prehistoric value, but eight parks were created just to protect fossils. This slide show will look at those eight parks and the different kinds of fossils they protect.

2. (Ancient Landscape) What are fossils? They are the remains of ancient life. They form under very special conditions and only a small fraction of the life that has existed on our planet has been preserved as fossils.

3. (Forest floor, rotting logs with fungus) What are the special conditions necessary for fossils to form? Usually, if something dies, it either rots away from bacteria and fungus, or is eaten by animals. (Scavengers are animals that live off of dead flesh.) So, a major factor in forming a fossil is rapid burial. This protects the organism from being eaten or exposed to bacteria.

4. Roadcut (Morrison Formation): Most fossils are found in sedimentary rocks. These rocks form when layers of silt, precipitates from water, or volcanic ash build up on the bottom of a lake, pond, marsh or sea. As the layers build up, they compress and harden into sedimentary rocks. There are four different types of

fossils that all form in their own special way: petrified fossils, carbon fossils, cast fossils and trace fossils.

5. Stump (Florissant Fossil Beds): Permineralization, or petrification, is one way that organisms are preserved as fossils. Highly porous materials like bones or wood can become petrified if they are buried quickly and thoroughly, before they start to decompose. Permineralized remains are the most common types of fossil found in the fossil NPS parks. Florissant Fossil Beds Nat. Monument has the most massive petrified fossils, the huge trunks of redwood trees. (Although there -are longer ones at Petrified Forest National Park, in Arizona).

6. Redwoods: Redwoods grew in the Florissant Valley of Colorado about 35 million years ago when the climate was much wetter and milder than it is today.

7. Eruption of Mt. St. Helens: A huge volcano stood nearby. When it began erupting, tons of ash was ejected into the air. Much of the ash fell on the sides of the volcano and mixed with melting snow and stream water, producing huge mudflows, or lahars.

8. Mudflows: Lahars such as these at Mount St. Helens are similar to those that flowed down into the ancient Florissant valley and covered the bases of the redwoods. The flows hardened into a rock called tuft.

9. Diagram: Water penetrated through the tuft, dissolving some of the minerals (mostly silica from the volcanic ash). The silica rich water penetrated into the tree trunks. As the silica solution filled in the cells, the cell walls were replaced and gradually the wood was turned to stone, or petrified.

10. Trio: This is what remains today. These stumps stand nearly 11 feet high.

11. Long Logs: Petrified Forest is a National Park where the largest concentration of petrified wood is found. Unlike Florissant where the stumps are found right where the trees were growing, these trees grew 225 million years ago in a vast forest on nearby mountains. They were washed away in a flood and buried in the bottom of a river. The silt that surrounded them gradually hardened into a rock. Then they slowly underwent a petrification process similar to the trees at Florissant. However, this wood is much more colorful than the wood at Florissant because in addition to silica, they contain minerals like iron and manganese that give them different hues.

12. Phytosaur bones: Wood isn’t the only thing that can be petrified. These phytosaur bones from Petrified Forest are all that remain of a phytosaur that died and was buried in silt before it was eaten by a Metoposaur or it started to decompose. Phytosaurs fossils are by far the most numerous vertebrates (animals with a bony backbone) found at Petrified Forest. Phytosaurs were primitive members of the ruling class of animals at that time, the Reptiles, including the dinosaurs and their ancestors.

13. Camarasaurus Skull (Dinosaur National Monument): Some of the most well known dinosaur fossils are found at Dinosaur National Monument in Colorado. This camarasaurus was alive nearly 200 million years ago......

14. Ancient Scene: and roamed the flood plains of a vast inland sea. It died and was buried in the silty bottom, laying there for millions of years and slowly becoming permineralized.

15. Picture Gorge, (John Day Fossil Beds): Petrified fossils from more recent times are found at several National Parks and Monuments. John Day Fossil Beds National Monument in Oregon contains an outstanding fossil record dating from 48 million years ago to 5 million years ago and has one of the world's most complete fossil records. The fossils were formed in a variety of ways. Hundreds of species of plants and animals fell into sinkholes or were buried by river and lake sediments or volcanic debris. There are four distinct rock formations represented in the John Day Fossil Beds. One of these is the .....

16. Clarno: Clarno Formation dating from 48 to 38 million years ago. At that time tropical to subtropical forests mantled the near coastal terrain.

17. Fossils: We know of these forests because of the splendid sample of fossil seeds, nuts, fruits, leaves, branches, and roots. The Clarno Nutbed is one of the finest fossil plant localities on the planet, with hundreds of species, many new to science, preserved. The Nutbed was deposited in a lake delta and covered with sediment. Other Clarno fossils (mostly leaves and wood) were preserved when huge lahars swept down from nearby volcanoes and covered parts of the forest. Eventually the plant matter became permineralized and today we have a very detailed look at this ancient world.

18.Badlands Present Day; This is how Badlands National Park, in South Dakota, looks today...

19. Mosasaur: but 80 to 65 million years ago, during the late Cretaceous, it was under water, part of an inland sea. This mosasaur is not a dinosaur but a marine lizard that fed on molluscs and fish. It was common in near shore marina waters. It died and was covered by marine sediments, eventually becoming petrified.

20. Oligocene: The inland sea receded, giving way to lush jungle. 37 to 23 million years ago the climate changed to a drier, cooler environment, and jungles gave way to grasslands. To the west stood the young Rocky Mountains. Flash floods periodically swept out from the Rockies to the plains below, and the mud trapped and buried many animals. Volcanic eruptions in that mountain range spewed forth millions of tons of ash that periodically blanketed the area.

21. Petrification: These creatures that were buried under the mud or ash slowly became petrified...

22. Oreodont: Like this Oreodont, an extinct animal that looked like a tapir, or pig. Oreodonts seem to have been very common, with many different members of the oreodont family having existed. Fossils of this type of animal are found at many different fossil sites. However, the family is now extinct with no living member or close relatives found anywhere on earth.

23. Agate Fossil Beds: Agate Fossil Beds National Monument is in northwestern Nebraska, along the Niobrara river.

24. Ancient Scene: 20 million years ago there was an ancient watering hole in the area, the ancestral Niobrara. Many different kinds of animals roamed the floodplain, like the large moropus, primitive dogs, hippopotamus, and rhinoceroses. A long drought resulted in the death of large numbers of these animals,

25. Fossils: When the rains finally came, large numbers of their skeletons were covered with sediments, and eventually permineralized.

26. Dozens of complete skeletons were discovered and give us a very accurate picture of what these animals looked like. Also, their discovery helps to give us a more complete picture of the entire fossil record and how animals have changed through time.

27. Hagerman Fossil Beds Present Day: Hagerman Fossil Beds, in Idaho, is another example of a NPS fossil site with petrified fossils that helped fill in the picture of changing life through time.

28. Hagerman Ancient Scene: The fossils from Hagerman are dated to be very recent compared to the other sites we have seen; only about 3.5 million years old.

29. Hagerman Horse: The fossilized animals found there are very similar to modern day species, with the most famous; the Hagerman horse (Equus simplicidens) being the oldest known ancestor to the modern horse of today.

30. Wasp: A second type of fossil-is called a carbon fossil. This happens through a different chain of events. Florissant Fossil Beds is world famous for the carbon fossils found there. When most people think of fossils, they tend to think of large, petrified bones, yet at Florissant Fossil Beds we find delicate fossils of insects and leaves. This is what we think happened....

31. Today Florissant lies on the western flanks of Pikes Peak in Colorado, a land of rolling meadows and conifer forests...Ancient Florissant was quite a contrast!

32. Ancient Scene: The climate was warmer and much more mild than today, perhaps subtropical, with lush vegetation. Many prehistoric animals including brontotheres, oreodonts, three-toed horses and marsupials roamed the lush valley.

33. As you may remember from earlier in the show, there was a huge volcano near ancient Florissant. When it erupted it sent out huge lahars (mudflows), some covering trees and causing them to petrify. Some of the lahars flowed into the valley and blocked a stream that flowed there, damming it.

34. Lake Florissant: A lake nearly 12 miles long formed behind this dam.

35. The volcano continued to erupt, sending out clouds of fine, powdery ash. This was blown by the winds down into the valley, and some of the ash fell into the lake, making a thin layer at the bottom.

36. Drawing: The ash covered up plant leaves and insects that had fallen to the bottom of the lake, protecting them from scavengers and decomposition.

37. Drawing:This happened time after time, over a period of half a million years. As the layers built up on the bottom of the lake, the lake began to fill in and gradually dry up.

38. Shale: As the layers built up, they began to compress and harden from the weight and turned into a sedimentary rock called shale. Because of the very thin layers, the rock is called a paper shale. Each layer represents a volcanic eruption or a period of sediment deposition on the bottom of the lake. The plants and insects gradually disintegrated, but the carbon in their bodies, the building blocks of their cells, stayed behind to leave a carbon fossil imprint.

39. Butterfly: When most people think of fossils they tend to think of huge dinosaur bones, not of delicate butterflies.

40. Butterfly fossil: yet at Florissant Fossil Beds we can find the remains of a butterfly that fluttered around the shores of ancient lake Florissant nearly 35 million years ago. The ash that covered the butterfly was so fine in texture, almost like talcum powder, that incredible details were preserved. Can you see the spots on the wings? The insect fossils found at Florissant are among the most detailed and abundant insect fossils in the world.

41. Fossil Butte National Monument is located in southwestern Wyoming. The high desert environment of today provides a sharp contrast with the past. Fifty million years ago this region was wet and subtropical.

42. Underwater scene: An enormous lake, 50 miles long and up to 15 mile wide, teemed with life. Fish and other organisms died,...

43. Sediments: fell to the bottom of the lake and were buried by organic matter and calcium carbonate. (Calcium carbonate is a precipitate that formed when water evaporated or the lake chemistry changed).

44. Compressions of sediments: As layers built up on the bottom of the lake, compression and heat turned the mud to rock.

45. Fossil fish: Today we find the carbon remains of 6 foot gar, bowfins, turtles, stingrays, and more than 20 other freshwater species of fish.

46. Shells: A third type of fossil is a cast or a mold fossil. Internal molds are fossilized replicas of the internal structure of an organism. (Fossil on the right is an internal mold) The best examples of this type of fossil are clams or

brachiopods. When a clam dies, over time the soft parts of the animal decay. The shell is left empty and this becomes filled with sediment. Eventually the shell dissolves away, but the sediments have hardened and remain as a fossil. The difference in casts and molds lies in what happens when the shell dissolves away. If the shell dissolves before its empty cavity is filled it leaves a void in the surrounding rock, which then becomes filled with sediment. The "cast" fossil that forms in the cavity shows signs of the outer shell features, while an internal mold fossil will only show signs of the shell's internal features.

47. Footprints: Trace fossils are the preserved remains or signs of animals left behind as they went about their lives. They include footprints, like these dinosaur footprints, or tracks, burrows, nests, eggs and feces.

48. Shell Fossils: Some remains of ancient life are found as original material

49. Baculites: This baculite from the Pierre shales of Badlands National Park was a type of mollusc, an ammonite. The original shell material, mother of pearl, has been preserved for over 65 million years.

50. Pseudofossil: This is a pseudofossil, or false fossil. The coloration that looks like fossil leaves is really a mineral discoloration.

51. Ancient Sea Floor: Index fossils are fossils that are indicators of a particular time in the earth's history. Plants and animals that flourished for a short period of time and then became extinct are indicator species. To go extinct means that all members of a species die, NEVER to be replaced. If they became fossilized and occur in a particular rock formation, they are an indication (index) of the relative age of the rock.

49. Trilobites: Trilobites were an important group of marine invertebrates during the Paleozoic era. Because old forms were constantly dying out while new ones evolved, many species of trilobites serve as index fossils defining the time periods in which they lived. As a group, trilobites were part of a mass extinction that occurred at the end of the Paleozoic, during the Permian, 250 to 260 million years ago. That sounds like a long time ago, doesn't it?

50. Geologic time drawing: Geologic time can be difficult to comprehend. The time that we have spent looking at these slides is just a fraction of an instant in comparison to the age of the earth. There are activities you can do to try to put it into a framework we can understand, or a drawing like this can give you an idea.

51. All that we know about the history of life on Earth comes from studying fossils and the clues they give us about the past. You've seen the different types of fossil we find, learned how they were formed and seen the National Park Service areas that protect them. Thanks to the protection by the National Park Service, we, and future generations, can continue to learn about the history of our earth.

Post Slide Show Activities:

Make a time line showing the time periods that the different national Parks represent. Draw pictures, from memory or research, of the ancient landscapes and animals.

If you haven't already, try to visit the National Park nearest you to learn more about the fossils. Some questions you could ask are:
What kind of fossils are found here?
How were they formed?
How old are they?
What era, epoch and period do they represent?
How are the fossils dated?
How does the method work?
What kinds of life forms are represented?
When were they discovered?
When was the area made part of the National Park System?

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Putting Together the Pieces

Teacher's Introduction

This unit is designed to build on concepts learned in the previous unit, "What Are Fossils?", and take those concepts a step further to discover what we learn from fossils and how we learn it. Through the activities in this section, students will learn about the concepts of observation, deduction and logic. They will gain an appreciation for how scientists use observed facts to make decisions about possible theories. By applying those skills to modern day ecosystems students will gain an understanding of the past and how scientific models are used to learn about the past.

Fossils are pieces of the past. Just like a puzzle, we have to put those pieces together in a logical manner to come up with a valid picture of the past. By observing present day systems and interactions in environments, and applying logic and deduction, we can make inferences about the past. Observation is seeing and noting facts. Inference is a proposed reason or assumption based on observation. Paleontologists use these two principles to put together a picture of what the past was like. By making observations of fossils they can make inferences about the animals or plants they represent. Also, by making observations of modern day plants and animals that are similar to the fossils, they can make inferences about the past. Of course, we have no way of knowing exactly what the past was like, but if we are methodical in our observations, we can catch a glimpse of what life was probably like. This glimpse can tell us much more than what lived when. Scientists, and students, can examine similar life forms today, if they exist, and look at the environment they live in and the interactions that occur to draw conclusions about ancient environment that existed. In this way, fossils can be indicators of the past climates and ecosystems and of climate change.

For example, at Florissant Fossil Beds National Monument, in Colorado, there are found the petrified remains of giant Sequoia trees. Today these types of trees grow on the western coast of the U.S., in a very moist, moderate climate which is nothing like the present-day climate of Colorado. So, we can draw one of two conclusions about the past: either the climate of ancient Colorado was very different, or, ancient redwoods were able to survive in a much different climate than the one in which they thrive today. Also, carbonized fossils of many different plants, like palms and ferns that today only grow in warm moist parts of the country, are found in the same general layers of rock. This added evidence helps us in drawing the conclusion that the climate used to be warmer and wetter there, for it would seem unlikely that so many different species would change so much in their physiology and environmental needs. This brings us to one of the major concepts of the unit, uniformitarianism.

The meaning of the concept of uniformitarianism is much simpler than the word itself. Simply put, it means that the present is the key to the past. The theory was formulated by the Scottish geologist, James Hutton. In the Theorv of the Earth with Proof and Illustrations, published in 1785, he stated his belief that the present is the key to the past and that processes now at work could account for all the geologic features of the earth, if sufficient time had passed. Hutton based his theory on the simple observation that weathering slowly disintegrates rocks. The debris that forms, gravel, sand, and silt, is transported by wind and water, and most of it ends up near or below sea level. Over time these layers are compacted and cemented and eventually turn into sedimentary rocks. In his theory, what remains uniform are the physical and chemical laws that govern geologic events.

A more modern term for the process is “actualism”. This term is used by some geologists because a uniform cause does not guarantee uniform results. For instance, the rate of sediment accumulation on the ocean floor today is not necessarily the same as the rate was a million years ago. Some scientists feel that the term actualism is more accurate because it doesn’t imply that the rates are uniform through time, only that the processes and physical laws have remained the same. Whichever term is used, the important concept is that the present is the key to the past.

While Hutton was applying the principle to geology, it can also be applied, to some extent, to environmental biology and ecology, for the same laws of biochemistry, energy flow and population dynamics that affect living systems today were in effect in ancient ecosystems. However, because organisms, as well as ecosystems, evolve and change they are not as constant through time as physical processes. But, by studying a present day ecosystem, one can make some inferences about the past.

A second major concept for this unit is evolution and natural selection. It is important to remember that the theory of evolution doesn’t provide all the answers. We do not know how important chance is in evolution or if life evolves by sudden or gradual changes or both. Nor does it answer the most compelling question of all; How did life begin? While discussing this theory of evolution, many strong feelings may emerge from the students. It is very important that no one be made to feel that their beliefs are “wrong” and the concept of theory will have to be emphasized. While some teachers shy away from such a controversial topic, discussing the theory can be an opportunity for talking about such important topics as the freedom of speech and belief.

Since humans first existed on the planet they have probably wondered about the origin of the earth. Stories explaining this concept date from nearly 5,000 years ago. The early Greek philosophers were the first to suggest that the world originated through and was controlled by natural processes and two Greek philosophers/scientists, Anaximander and Empedocles, suggested evolution about 500 B.C. The concept was not widely accepted, perhaps because two of the more popular philosophers, Plato and Aristotle, believed in a perfect world which stayed the same all through time. Throughout much of history most people believed that the world had been recently created by God. In the 1 6th century the works of the Greeks were discovered and people began to question some of the religious beliefs. In the 1 8th century Hutton’s principle of uniformitarianism suggested the age of the earth was much greater than generally believed. In the 19th century Lamarck put forth the theory of evolution but it was not widely accepted. He believed that things had evolved gradually, from the simple to the most complex and that in each generation organisms could change their characteristics to cope with the environment. They could pass these changes on to their offspring.

In 1859, Charles Darwin published his theory of natural selection. Alfred Russell Wallace came up with the same theory. Like Lamarck, they believed in evolution from simple to complex organisms but also believed change was caused by natural selection. Darwin’s theory was based on four assumptions: that most species produce far more offspring than could possibly survive, that individuals vary and some variations may help those individuals have a better chance of survival, that an individual’s chances of survival will be affected by the environment in which it lives and, those individuals best suited to their environment are more likely to survive and pass on their characteristics. Darwin saw two main sources of evidence for his theory. One was by looking at domesticated plants and animals. People have deliberately changed their characteristics by breeding together specifically chosen animals or plants for desirable traits. This artificial selection shows how traits can changed over many generations. Also, in his travels over the globe, Darwin noticed that plants and animals that live in similar environments look similar and have similar adaptations that help them to survive in their environment. He saw this as evidence of natural selection.

Darwin did not understand the reasons why variation occurred in populations but early in the 20th century biologists discovered genetics. In the 1920’s a new theory was worked out which brought together genetics and an updated version of the theory of natural selection.

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Unit Goals and Objectives

Goal: Students will realize the importance/value of studying fossils.
Objectives:
Students will identify 2 things we can learn from fossils.
(Climate change and changing adaptations.)

Goal: Students will understand how we formulate models of the past.
Objectives: Through activities and discussion students will apply the concepts of natural selection to present and past ecosystems.
Students will comprehend, through activities and discussions, how models work in forming theories.
Students will differentiate between observation and inference
Students will use clues presented to them to compare and contrast ancient animals to their modern day counterparts, noting adaptive changes.

Concepts

Observation: Seeing an occurrence or recognizing a fact.
Theory: A proposed explanation for a situation based on observation D facts.
Inference: A conclusion derived from observations.
Uniformitarianism: The concept that the present is the key to the past. The concept was formulated by the English geologist Lyle in the 18th century. The theory didn't receive much attention until it was promoted by the Scottish geologist, Hutton.
Natural Selection: Survival of the fittest
Evolution: The long term change in organisms caused by the survival the fittest. It often takes place over millions of years.

Vocabulary

Organism: A plant or animal.
Food Chain: A chain of organisms through which food energy is passed.
Herbivore: An animal that eats only plants.
Carnivore: Usually an animal, sometimes a plant, that eats other animals.
Omnivore: An animal that eats both plants and other animals.
Producer: An organism that can produce it's own food. Plants produce food when they turn sunlight into food through photosynthesis
Consumer: An organism that feeds on other organisms.
Prey/Predator: Prey is an animal that is killed and eaten by another animal, the predator.
Natural Selection: The survival of the fittest.
Adaptation: Characteristic that gives an organism a better chance of survival. Through evolution these characteristics are enhanced in a species.
Extinction: When all members of a species have died out.

Sources For Further Information

The Young Scientist Book of Evolution, The Young Scientist Book of Evolution, Barbara Cork and Lynn Bressler, Usborne Books, EDC Publishing, Tulsa Oklahoma. ISBN 0-86020-867-2

The Children's Picture Prehistorv: Prehistoric Mammals; Our world after the dinosaurs, Anne McCord, 1977, Usborne Books, EDC Publishing, Tulsa, Oklahoma. ISBN 0-86020- 128-7

My Life with Dinosaurs; How two dinosaur experts bring prehistoric monsters to life. Stephen and Sylvia Czerkas
Hands-on dinosaur reconstruction kits. Hard pieces are encased in a clay matrix. Students "excavate" the fossils (tools included) then reconstruct and paint (brush and paint provided). The reconstructed animal is 9" by 12". The kits are available from Acorn Naturalists, 17300 E. 17th St. #J-236 Tustin, CA, 92680.

Dimensional Dinosaurs; Build three different dinosaurs with die cut white foam board pieces. Children add details, texture and color using felt pens or watercolors. Lesson plans and work sheets included. Kits packaged for 24, 30, 36, or 100 students. The cost varies with quantity ordered. Order from A Child's Art Factory, 7371 Player Dr. San Diego, CA 92119.

Classroom Activities
Classroom Activity 1
Keys to the Past

Objectives: Students will learn what an inference is and differentiate between inference and observation. They will examine a scene and a series of statements about the scene and then determine which statements are observations and which are inferences.

Background: Modern science is based on observation and inference. Observation is seeing and noting facts. Inference is a proposed reason or assumption based on observation. Paleontologists use these two principles to form theories, or put together a picture of what the past was like. By making observations of fossils they can make inferences about the animals or plants they represent. Also, by making observations of modern day plants and animals that are similar to the fossils, they can make inferences about the past.

Materials:
Handouts (3) for each student or team:
Dinosaur scene

List of statements
Petrified Bones and Tracks page

Procedure: Discuss the difference between observation and inference then pass out the handouts.
Have the students work individually or in teams. They will determine whether each statement is an observation or an inference. Later, go over their answers as a group, discussing the logic used in making their choices.

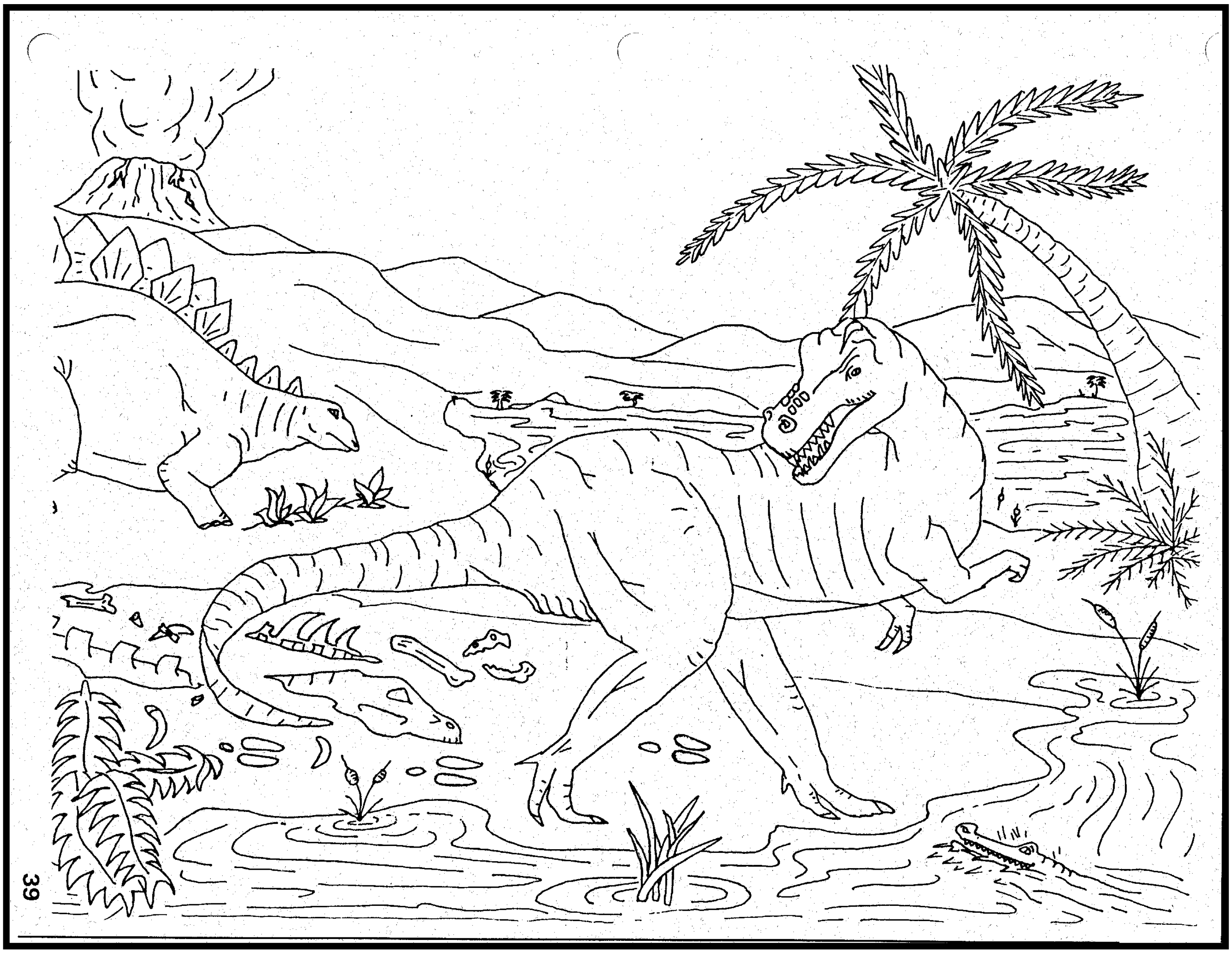
Answers:

Dinosaur Page		**Tracks and Bones**
1. 0	10. 1	1. 0
2. 1	11. 0	2. 1
3. 1	12. 1	3. 0
4. 0	13. 0	4. 1
5. 1	14. 1	5. 0
6. 0	15. 0	6. 0
7. 1	16. 1	7. 1
8. 0	17. 0	
9. 0	18. 0	

Dinosaur Scene: A time machine has been invented that travels into the past and takes pictures, sending them to the present. You are asked to look at one of the pictures and interpret what you see. Put an “O” before the statements that are observations and an “I” before the statements that are inferences.

1. The volcano is erupting.
2. The camptosaurus is going to eat the stegosaurus.
3. The stegosaurus will run into the water to escape.
4. The camptosaurus is leaving tracks in the ground.
5. The ground where the camptosaurus is walking is wet.
6. There are plants growing in the water.
7. The camptosaurus is going into the water to eat the plants.
8. There is a tree growing next to the river.
9. The tree looks like a palm tree.
10. The climate is warm.
11. The stegosaurus is eating the plant.
12. The stegosaurus is an herbivore.
13. There are bones from a dead animal by the shore.
14. The camptosaurus killed the animal.
15. Some more bones are in the water.

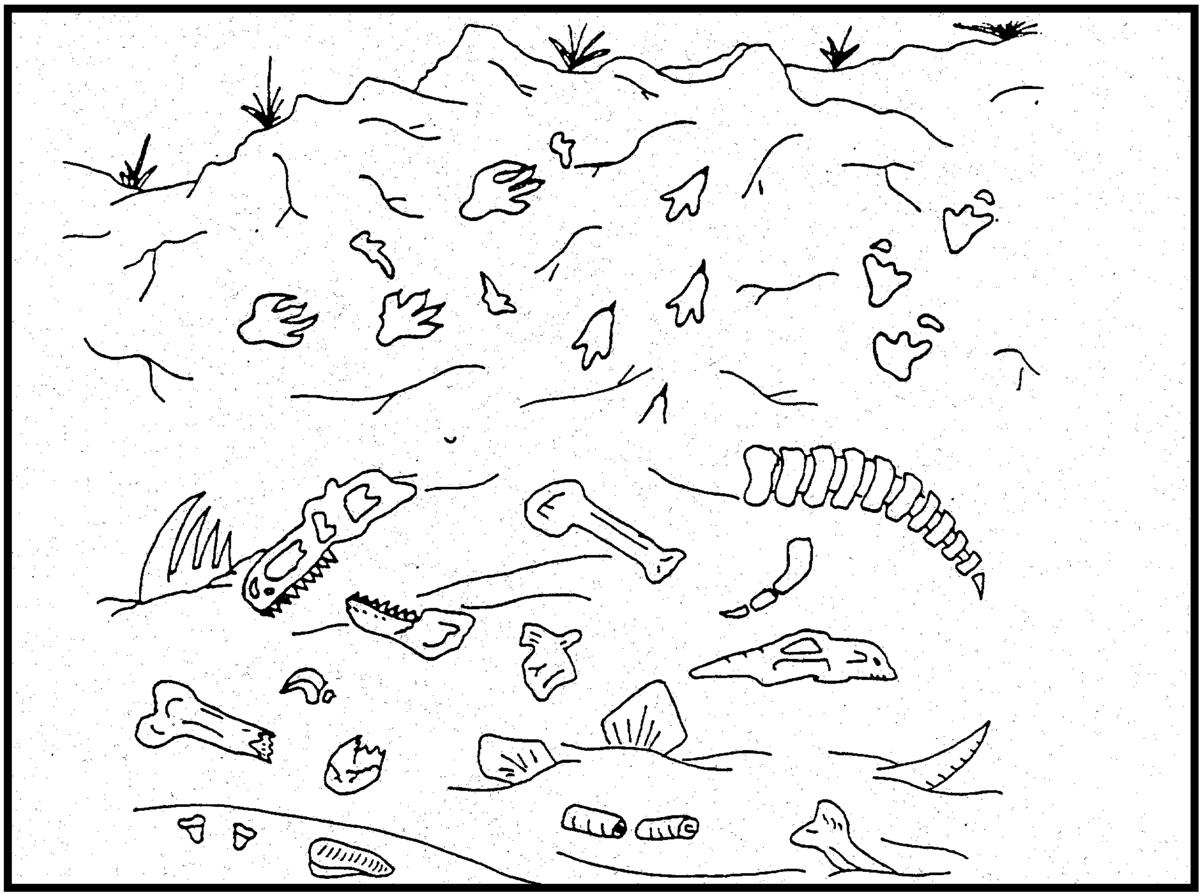
16. The camptosaurus can't swim and will drown.
17. Lava is coming down the sides of the volcano.
18. The camptosaurus has sharp teeth for eating meat.



Tracks and Bones: You are a paleontologist and you have just discovered a layer of rock with many fossils in it, both petrified bones and tracks. Decide whether the following statements are observations or inferences.

1. There are tracks from three different animals in the rock.
2. One animal was chasing another animal.

3. Two different animals died in this spot.
4. When the animals walked here the ground was wet.
5. One of the animals that died here had bony plates.
6. One of the animals that died here had sharp teeth.
7. The animal that had sharp teeth ate meat.



Classroom Activity 2
Distant Relatives

Objective: Students will match clues about ancient mammals to the corresponding mammals. They will then use that information to match the ancient mammals to their modern counterparts.

Background: Mammals have existed since the reign of the dinosaurs. At that time mammals were small, mostly nocturnal creatures. When the dinosaurs became extinct, mammals' characteristics (fur, live-bearing, nursing their young,) allowed them to survive. They adapted and radiated to fill the niches which were abandoned by the dinosaurs. The fossil record allows us to compare and contrast these early mammals with modern ones. Some ancient mammals gave rise to the modern species while others became extinct with no living counterparts. Paleontologists use comparative anatomy, using the skeletons of modern animals to gain information about the possible traits of the fossils they are studying. Also, by learning about the natural history of the living counterparts, scientists can sometimes draw conclusions about the natural history of the ancients and how they may have fit into their ecosystem.

Materials:
copies for each student of:
clues about ancient mammals (follows)
ancient mammals (follows)
modern mammals (follows)
Reference books with natural history information

Procedure:
Part one:
Discuss information from the background section with the students. Pass out the clues and illustrations of the animals. Students read the clues about the ancient mammals and match those clues to the corresponding animal.

Part two:
Using common knowledge about the modern animals and further research if desired, students match the ancient mammals to their modern counterparts.

Modern Mammal or Family	Fossil Mammal	Matches Clues
Perissodactyla Hoofed feet with 1 or 3 toes	Miohippus Moropus	#4 #2
Artiodactyla Hoofed feet with 2 or 4 toes Camel, antelope, llamas	Stenomylus	#6
Carnivora Special teeth for tearing meat Cat and Dog family, and others	Western Sabertooth cat	#3
Rodentia Chisel-like front teeth for gnawing Praire Dog, mice, beavers etc.	Castorides	#5
Proboscidea Huge size, long trunk Elephant	Zygophodon	#1

Go over the answers (provided) discussing the similarities and differences. In the answer sheet, first listing for each modern mammal is the order. Orders are classifications of animals, based on physical and physiological similarities.

Follow up:

Talk about the clues given for the fossil mammals, Which one of the clues are observations that could be made from studying fossilized animals and which clues are inferences?

Discuss what environmental factors could have influenced changes seen over time (evolution). For example, today camels live in areas with shifting sands and have soft pads on their feet, stenomylus had hooves and lived in savannah-like grasslands. How wood these different types of feet help in each environment? Modern horses have only one toe, a hoof, while miohippus had three toes. One toe means less surface area touching the ground and is an advantage in speed. Castroides was considerably larger than modern beavers, and would have needed much more food to survive.

Clues:

1
*ate plants
*had huge tusks that stood out
*may have used the tusks for fighting rival males
*lived in western North America
*very large size

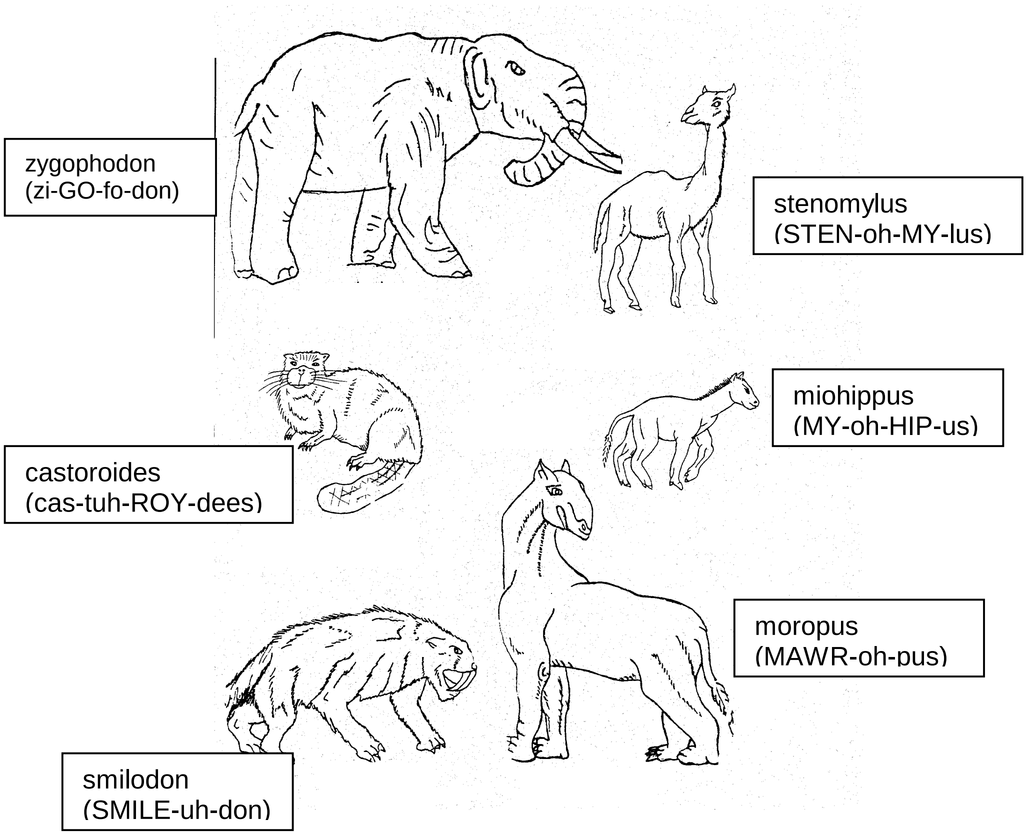
2
*ate leaves, grass and roots
*claws on its front feet for
*head like a large horse
*sloping back

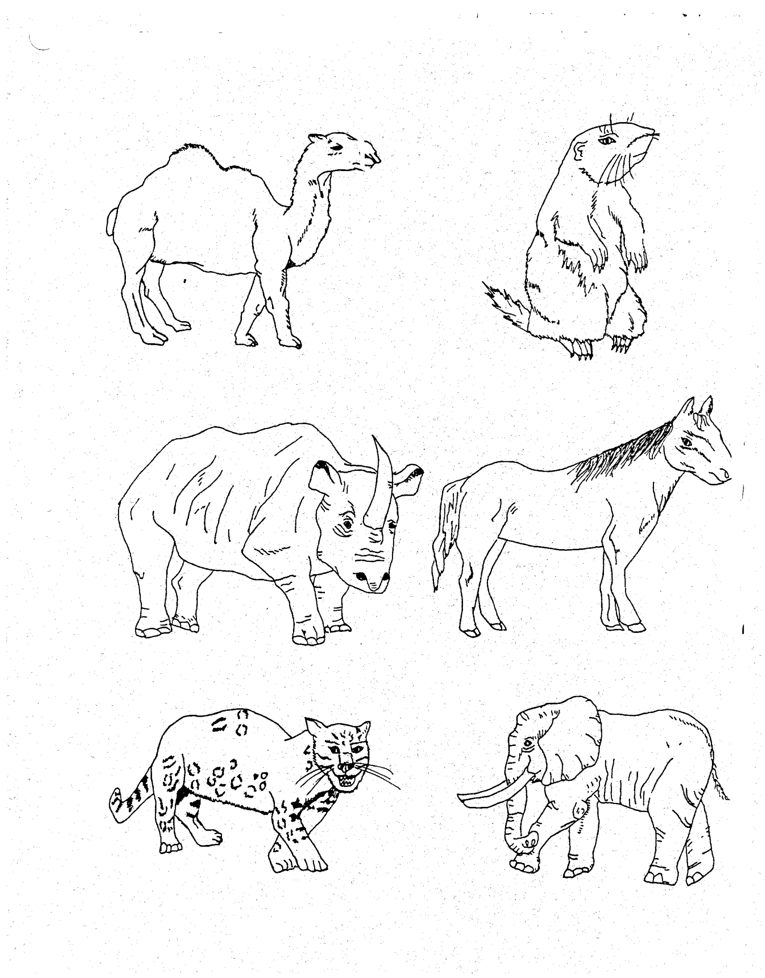
3
*ate meat
*had two long, pointed front teeth that hung down from its upper jaw
*heavily built with large, powerful front legs
*claws on feet

4
*ate leaves and grass
*was about the size of a sheep
*had 3 toes on each foot
*had long legs

5
*ate water plants
*lived in lakes and ponds
*was almost 8 feet long and weighed as much as a black bear

6
*ate plants
*looked camel-like
*had hard hooves


zygophodon
(zi-GO-fo-don)
stenomylus
(STEN-oh-MY-lus)
miohippus
(MY-oh-HIP-us)
castoroides
(cas-tuh-ROY-dees)
moropus
(MAWR-oh-pus)
smilodon
(SMILE-uh-don)



Classroom Activity 3
Make a Diorama

Objectives: In this project students will combine research skills and art activities to produce a diorama showing an ancient scene. Through research they will reconstruct an ancient ecosystem, showing the crucial elements of that ecosystem. They will apply the concept of uniformitarianism when reconstructing the past.

Background: The meaning of the concept of uniformitarianism is much simpler than the word itself. Simply put, it means that the present is the key to the past. The theory was formulated by the Scottish geologist, James Hutton. In 1785 he stated his belief that the present is the key to the past and that processes now at work could account for all the geologic features of the earth, if sufficient time had passed. In his theory, what remains uniform are the physical and chemical laws, like gravity and weathering, that govern geologic events.

A more modern term for the process is "actualism". This term is used by some geologists because a uniform cause does not guarantee uniform results. For instance, the rate of sediment accumulation on the ocean floor today is not necessarily the same as the rate was a million years ago. Some scientists feel that the term actualism is-more accurate because it doesn't imply that the rates are uniform through time, only that the processes and physical laws have remained the same. Whichever term is used, the important concept is that the present is the key to the past.

While Hutton was applying the principle to geology, it can also be applied, to some extent, to environmental biology and ecology, for the same laws of biochemistry, energy flow and population dynamics that affect living systems today were in effect in ancient ecosystems. However, because organisms, as well as ecosystems, evolve and change they are not as constant through time as physical processes. But, by studying a present day ecosystem, one can make some inferences about the past.

Materials:

cardboard boxes	glue
construction paper	scissors
modeling clay	yarn
etc.	

For research materials, use encyclopedias, sources from the list of further information, magazine articles, or contact a National Park to obtain information (list provided) about that park.

Directions:
Research a period and place in geologic history. With the information you obtain, make a diorama showing the ancient ecosystem. Some things to consider are; What animals do you wish to portray? What did those animals eat? What adaptations did they have that would help them to survive? What dangers did they have to be on the look out for? What was the climate like? What was the landscape like? Look at your sources of information and decide what clues were

used to come up with this information. Are there any modern day animals that are similar and that live in a similar environment? Use the present as a key to the past by researching those animals to gain insights into their lives.

Follow-up: After the students have completed their dioramas, ask them to give an oral presentation about what they learned, and how they applied the concept of uniformitarianism to their project.

Agate Fossil Beds National Monument P.O. Box 427 Gering, NE 69341 (308) 436-4340	Fossil Butte National Monument P.O. Box 592 Kemmerer, WY 83101 (303) 877-4455
Badlands National Park P.O. Box 6 Interior, SD 57750 (605) 433-5361	Hagerman Fossil Beds National Monument P.O. Box 570 Hagerman, ID 83332 (208) 733-8398
Dinosaur National Monument P.O. Box 210 Dinosaur, CO 81610 (303) 374-3000	John Day Fossil Beds National Monument 420 W. Main St. John Day, OR 97845 (503) 575-0721
Florissant Fossil Beds National Monument P.O. Box 185 Florissant, CO 80816 (719) 748-3253	Petrified National Forest Park Petrified Forest, AZ 86028 (602) 524-6228

Classroom Activity 4
Pollen Analysis

Objectives: Students will be introduced to the value of pollen analysis in reconstructing the past.

Background: Pollen has three characteristics that make it very valuable for studying the past and reconstructing ancient ecosystems. The most important is that pollen can be fossilized if it is buried under the right circumstances. The exine of pollen is very durable and almost indestructible and the pollen is extracted from the surrounding rock by dissolving the rock in acids.

Another attribute is its distinctive shape. Each kind of plant has its own unique shape of pollen, different from every other kind of plant. Like a person’s fingerprint, this unique shape can be used to identify a particular plant.

Another important characteristic of pollen is its size. These microscopic “fingerprints” can be carried by the wind for great distances before they fall to the ground to become, potentially, fossils. “So, fossilized pollen can give clues about the regional environment instead of just telling about what grew in a particular area. Go over These important characteristics of pollen with the class before starting the activity.

As an example of the broader look at the past that we can obtain from studying pollen we will look at an example from Florissant Fossil Beds National Monument in Colorado. There we find a tremendous variety of very intricate fossils of leaves and insects from a period of time nearly 35 million years ago, during the late Eocene epoch. Due to volcanic activity, a stream was dammed to form a lake and many, many layers of leaves and insects that fell into the lake were buried under layers of volcanic ash and preserved as detailed fossils. These fossils give us much information about what grew right next to the lake and fell into it.

But, if you extract the pollen from the shales by dissolving the shales in acid a wealth of further information is revealed. Many species of plants that are NOT represented as leaf fossils are discovered by looking at the fossil pollen. This pollen was carried by the wind to land in the lake and we can gain an idea of what the whole region was like by identifying it.

However, it is important to remember that plants that are insect pollinated do not produce as much pollen as plants that are wind pollinated. This means that insect pollinated plants would not be as well represented in the fossil record and the fossil record would not reflect relative abundance.

Directions: Pass out the handout. Ask the students to look at the list of plants that are found as “macro” fossils (leaves). Using encyclopedias or plant guide books, have them research some of the plants to find out what kind of climate they live in and associations with other plants. What conclusions can they draw about the ancient climate at Florissant? Now have them look at the plants that show up in the fossil pollen record. Are there any further insights that can be drawn? (The pollen analysis gives a more regional picture and some of the plants reflect a drier, more upland ecosystem).

Follow up: Florissant Fossil Beds is located on the western flanks of the Pikes Peak region. It is in the Montane life zone, one of five life zones encountered as you travel upward in elevation in the Pike’s Peak region. The great plains to the east of the mountain are one life zone. As you move upward you pass through the Foothills, then into the Montane ecosystem (where Florissant is located) on up into the sub-alpine life zone and finally near the top of the peak, the alpine, or tundra, life zone. Just as today, life zones and plant communities are influenced by altitude, and so it must have been in the past, with the Florissant Valley being very lush and wet because of the stream and lake and the surrounding uplands being colder and dryer.

Microclimates are pockets of vegetation where the climate is different from the surrounding area. Some of the factors influencing a microclimate are shown below. Have the students locate a microclimate in their neighborhood or nearby park. How is it different from the surrounding area? What factors are influencing the microclimate? If this microclimate were to become a fossil deposit, would it be misleading about the general climate? How would you gain a better picture of the overall climate? (By studying the fossil pollen).

NORTH-FACING SLOPES

1. Shady (receive indirect rays of sun)
2. Snows melt slowly
3. Rainwater evaporates slowly
4. More soil moisture available for plants
5. Larger and more abundant plants

SOUTH-FACING SLOPES

1. Sunny (receive direct rays of sun]
2. Snows melt rapidly
3. Rainwater evaporates quickly
4. Less soil moisture available for plants
5. Smaller and fewer plants

Pollen Analysis Handout

There are three things about pollen that make it very valuable for studying the past. One is that pollen can be fossilized if it is buried under the right circumstances. Another characteristic is its distinctive shape. Each kind of plant has its own special shape of pollen, different from every other kind of plant. Like a person's fingerprint, this shape can be used to identify a particular plant. Another characteristic of pollen is its size. Because it is so small pollen can be carried by the wind for great distances before it falls to the ground. So, fossilized pollen can give clues about what the climate of a whole region was like, instead of just telling about what grew in a particular spot. However, it is important to remember that plants that are insect pollinated do not produce as much pollen as plants that are wind pollinated. How do you think that would affect the fossil record when we look at fossil pollen?

As an example of the bigger picture of the past that we can see when we study pollen we will look at Florissant Fossil Beds National Monument in Colorado. At Florissant we find many different fossil leaves and insects that are about 35 million years old. Because of mud flows from a huge volcano that was active back then, a lake was dammed and many, many layers of leaves and insects hat fell into the lake were buried under layers of volcanic ash and preserved as detailed fossils. These fossils give us a great deal of information about what grew right next to the lake.

But, pull out a microscope to look at the fossil pollen and the picture of the past becomes much bigger. Many species of plants that are NOT represented as leaf fossils are discovered by looking at the fossil pollen. This pollen was carried by the wind to land in the lake and we can get an idea of what the whole region was like by identifying it.

Directions: Look at the list of plants that are found as “macro” fossils (as leaves). Using encyclopedias and plant guide books, research some of the plants to find out what kind of climate they live in and associations that they have with other plants. What conclusions can you draw about the ancient climate at Florissant? Now, look at the plants that show up in the fossil pollen record. Research those plants and find out what kind of climate they are found in and what associations they have with other plants. Does looking at the fossil pollen record give you any further insights into the ancient climate?

Leaf and Pollen Comparison List

When researching these plants, remember that they were growing nearly 35 million years ago. Some of them are now extinct. However, they were very similar to modern day plants and have been included into modern day plant families (names of families end with the suffix "aceae"). So, if you can't find a particular kind of plant, look up the family. The plants listed would have had very similar growth habits and needs as other members of the Family.

Fossilized plants from Florissant
Seauoia, Family Taxodiaceae
Poculus, Family Salicaeae
Athavana, Family Sapindaceae
Saoindus, Family Sapindaceae
Cercocarous, Family Rosaceae

Fossilized pollen from Florissant
Junlans, Family Juglandaceae
Celtis, Family Ulmaceae
Pseudotsuga, Family Pinaceae
Family Chenopodiaceae
Family Amaranthaceae

Follow-up: What did you discover? Did the plants that had fossilized pollen seem to grow in a different type of life zone or environment than the plants with fossil leaves? Life zones, in general, are influenced by altitude and latitude. For example, the entire North American continent is divided into three major life zones: The Boreal, or northern zone also includes areas above 8,000 feet in elevation, the Austral, or southern zone includes areas between 3,500 feet and 8,000 feet in elevation and the Tropical zone which can include areas below 3,500 feet. The U.S. can be divided into regions with each region having its own climate and life zones. In Colorado today there are five different life zones that are determined by the altitude.

There were also different life zones in the ancient Florissant region. The valley itself was very lush and wet, but the highlands around it were drier and cooler. The kinds of plants that grow in a life zone are also influenced by "microclimates". Some of the factors that influence a microclimate are listed below. What kind of life zone do you live in? Can you find any microclimates in your neighborhood?

NORTH-FACING SLOPES
1. Shady (receive indirect rays of sun)
2. Snows melt slowly
3. Rainwater evaporates slowly
4. More soil moisture available for plants

5. Larger and more abundant plants

SOUTH-FACING SLOPES

1. Sunny (receive direct rays of sun)
2. Snows melt rapidly
3. Rainwater evaporates quickly
4. Less soil moisture available for plants
5. Smaller and fewer plants

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Outdoor Activities
Outdoor Activity 1
Food Chain Game

Objectives: After playing this game the students will apply the concept of natural selection to present and past ecosystems. They will understand how models work in forming theories and how the present can be a key to the past (uniformitarianism).

Background: No materials are needed for this game. However, the game should be played in an open area with no obstructions that the students can run into or trip over. Tag, rather than tackle, may have to be emphasized to certain individuals in the group. This game can be adapted to any environment or period in time. Choose two food chains: one that could exist in your environment today and one that existed in an ancient environment. Present day examples are: grass, prairie dog, badger; aspen, elk, mountain lion. Examples from the past are cycads, apatosaurus (herbivore), tyrannosaur (carnivore); fern, oreodont (herbivore), sabertooth cat (carnivore).

Procedure: Divide the students into three equal groups. Using the present day food chain, those in group 1 are the plant species of your chosen food chain, members of group 2 are the herbivorous species of your food chain and group 3 members are the carnivorous species.
Group 1 members scatter out in the playing field, rooted in place. Group 2 members stand spread out on one side of the leader, Group 3 members on the other side of the leader.

At signal, herbivores will try to reach a plant and carnivores will try to tag a herbivore. If an herbivore reaches a plant it is safe; it has procured food and will live to play another round. If a carnivore tags a herbivore it has caught its meal and will survive to play another round.

Any species that is “eaten” becomes the species that ate it, as it is incorporated into that animal’s body. Plants tagged by a herbivore will become herbivores for the next round, herbivores that are eaten will be carnivores for the next round. Any animal that is not successful at obtaining food in a round dies. Its body decomposes and adds nutrients to the soil, helping plants to grow. Thus, any unsuccessful animals will become plants for the next round.

Play several rounds (enough for the populations to go through considerable fluctuations) with the present-day food chain then play some rounds with the ancient-day food chain.

Follow up: When the time period is up, assemble the students and discuss these concepts: What happened during rounds where food was plentiful for one of the species? How did that affect the next round? Did anyone remain the same species for the entire game? What advantage (adaptation) did that person have? Are they particularly fast or agile? Or, did they apply any strategies?

What adaptations do plants have that can lessen their chances of being eaten? Perhaps they don’t taste good, grow in inaccessible places, have thorns or spines, or have short reproductive cycles so they are able to produce seed and ensure survival of the species even if they are eaten.

What adaptations do animals have that could help chances of survival? Speed, good vision, and behavior can all be factors.

Classroom Follow-up: Research the species that were involved in your food chains, past and present. What adaptations do the members of the present-day ecosystem have that can help them to survive? How do these adaptations affect future generations? Discuss survival of the fittest and how that affects the characteristics of offspring. Evolution is the sum of many generations being affected by survival of the fittest and chance.

What happened when you played the game using the members of an ancient food chain? Did the same principles apply? Do we know for sure that the same principles applied or are we making an assumption? What are we basing our assumption on? Is it a valid assumption?

When you played the game with the ancient food chain, the students had to imagine that they were in the ancient environment. How has the climate changed? Would those plants and animals survive today? Research the members of the ancient food chain. What clues do we find in the fossils of the ancient ecosystem? How do these clues help us form theories about the actual plants or animals?

Have the teacher or a classmate keep track of the numbers of the different animals and plants from each round and graph the fluctuations. What patterns, if any, do you see?

Outdoor Activity 2
Adaptation Game

Objectives: This game gives students an opportunity to consider why and how life forms adapt.

Background: Adaptations are physical or mental characteristics that help an organism to survive. Over time, natural selection and evolution enhance adaptations. When change occurs in the environment, different characteristics may help or hinder the individual animals in a population. If those animals are helped, they survive the changing situation and pass on the genes which give those characteristics to their offspring. If the animals are hindered, then the species may go extinct.

It is important that the students remember that none of the changes or adaptations happen quickly in nature. Some of the environmental changes take place within one lifetime while others may take thousands or millions of years. Some adaptations, like insects' immunity to a pesticide, occur over a few generations, while most others take millions of years to develop.

Procedure:

1. Photocopy pages of "Possible Adaptations" and cut out each adaptation so it is separate.
2. Divide students into two teams and have each group number off so that each student has a number.
3. Have the teams line up about 40 feet apart facing the other team.
4. Place the adaptation cards in the center between the two teams.
5. Have a copy of the "Changing Situations" list in hand.

Now you are ready to play the game. Call out a "Changing Situation" and a number. The students whose numbers have been called run to the center and pick up one or more cards until they have adaptations that will help their team cope with the change. They return to their team with the cards they picked up.

When the players return to their teams with the cards have them read out loud the solutions they chose and explain why they are helpful. All cards that offer a reasonable solution to the problem count as a point for that team. Return all cards to the center after the adaptations have been discussed. The team with the most points wins.

Changing Situations

Your Predators become camouflaged	Disease and insects kill almost all of the trees you depend on
Your prey becomes camouflaged	The climate becomes very cold
The plants you eat become extinct	The animals you eat develop armor
Your predators begin to run faster	Other animals find and eat your eggs
The area you live in turns to desert	The ocean you live in dries up
The plants you eat develop spines	Your food supply becomes seasonal
Humans use pesticides to kill you	The animals you eat start to only come out at night
The animals you eat begin living underground	The plants you eat develop a bad taste

Adaptations

Become camouflaged	Develop better night vision
Hibernate	Learn to store food
Build an underground home	Develop muscles and claws for digging
Shed more fur to keep cooler	Become warm-blooded
Develop longer legs	Develop lungs for breathing
Sleep in the day and hunt at night	Migrate
Develop armor	Incubate eggs within your body (mammals)
Lay camouflaged eggs	Grow quills
Shed less fur	Grow fangs
Develop claws for climbing trees	Develop a better sense of smell
Develop a better sense of hearing	Develop a way to store water in your body
Become immune to pesticide	Develop new teeth and digestive system so you can eat different plants
Live with others of your kind and take turns keeping watch for predators	

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Slide Show Script

1. Title Slide: Paleontology is the science of studying ancient life. To do this we have to find fossils, or clues, and put them together to form a picture of the past. This slide show will examine the ways we put those clues together and how we interpret them.

2. Geologic Map: Because fossils only form under special conditions they are only found in certain types of rocks. Geologists make maps of different types of rocks and where they are found. Each color on the map shows a different geologic rock formation.

3. Stratigraphic Column: and paleontologists use the information from those maps and what they know about different formations and the kinds of rocks that fossils form in to get a better idea of where to look for fossils.

4. Dig Site: Once they know where to look, they may spend weeks combing the area for fossils that have eroded away and are exposed on the surface.

5. Old excavation site (Agate Fossil Beds): In the early days of paleontology, when geologists found fossils they would simply dig them up and take them back to places where they could be displayed.

6. Taking Photographs: Today, we have a better understanding of all the clues that the rock around a fossil can offer so excavations are completed very carefully. Each site is carefully mapped, photographed, and notes are taken about depths and orientation of the fossils.

7. Reliefed fossil: Then a decision is made about how to deal with the fossil. If it is too fragile, or the surrounding rock has many clues about the ancient environment, it may be left in place. If the fossil can be removed, it is carefully "reliefed", with the surrounding material carefully chipped away.

8. Plaster Cast: Then it is surrounded with rags wet with plaster. When this hardens, it makes a cast around the fossil, so it will be safe until is taken back to the laboratory.

9. Sometimes moving these fossils can be quite a job!
Especially if the dig site is located in a remote area.

10. Helicopters are sometimes used.

11. In the Lab: Once in the lab, very delicate care is taken to remove the plaster cast and the rock surrounding the fossil

12. Lab, Continued: and sometimes the fossil is studied on a microscopic level.

13. Coelophysis (Petrified Forest Nat. Park): Sometimes an entire, complete skeleton is discovered, but usually just some of the bones of an animal are found and the bones have to be placed back together again to get an idea of what the animal looked like.

14. Pronghorn Antelope: Paleontologists use a technique called comparative anatomy to get clues. They study modern animals that seem to be similar for clues about how the bones fit together, the size of muscles that attach to certain types of bones, and how those muscles work, to come up with an idea of what the animal looked like and how it moved.

15. Bone (Swan from Hagerman Fossil Beds): Certain characteristics of bones help to identify the family of animal that they originated from. Bird bones, like this bone from a swan that lived at Hagerman Fossil Beds N.M. about 3 million years ago, are hollow, and are easily differentiated from mammal bones, based on this characteristic. Also, different types of bones yield more information than others. By examining a leg bone and using comparative anatomy and physics, a paleontologist can learn about adaptations the animal had for digging, running, climbing, or catching prey, for examples. However, rib bones would only give clues to the general shape of the animal's torso.

16. Oreodont Jawbone (Badlands) Teeth can tell us what an animal ate. Herbivores, like this oreodont from Badlands National Park, are plant eaters and have squared, flat teeth for grinding up plant matter. These teeth are very different

17. Borophagus (Hagerman Fossil Beds):from the sharp, tearing teeth of a carnivore (meat eater) like this borophagus, a hyaena like dog found at Hagerman Fossil Beds in Idaho.

18. Syndyoceras (Miocene deer from Agate Fossil Beds N.M.): If bones from several animals are found together they can provide clues about interactions. If they are from different kinds of animals we learn about different associations. If they are from the same kind of animals we can learn about the social structure that may have existed between those animals.

19. Parahippus: Sometimes fossil animals are discovered that are ancestors of modern day animals. This parahippus was an ancestor of the horse family, and looked similar to modern day horses except it had three toes instead of one (a hoof).

20. Hagerman Horse: We can look at the evolution of the horse family through time by looking at their fossils. The Hagerman horse, Equus simplicidens roamed the ancient landscape of Idaho, 3.5 million years ago.

21. Articulated Fossil Horse: We can study the skeleton to see how the horse family changed and evolved with time

22. Zebra: and compare it to modern members of the family. modern animal to learn more about the ancient one.

23. Stenomylus Skeleton: Also, when we find fossil animals that are ancestors of modern day animals we can look at the modern descendants of that family of animals and infer how the animals may have interacted. This stenomylus from Agate Fossil Beds is an ancestor of camels.

24. Stenomylus Interacting: The concept of looking at the present as a key to the past is called uniformitarianism. It is long word that means something very simple. The processes that we see around us today, like erosion, sedimentation, and, to some

extent, animal behavior, were also happening in the past. So, we can use the present as a key to understanding what life was like for the fossils that we find today.

25. Fern: Once an animal is reconstructed, how do we reconstruct its environment? It is helpful if there are fossil plants from the same site, or from similar sites from the same time period. Ferns today
require a specific kind of environment, a climate that is moderate and very wet. Using the present as a key to the past, we could assume that a…

26. Fossil Fern (Florisssant Fossil Beds): ....fossil fern would need the same kind of climate. When the plants are similar to modern day ones, we can look at modern day plants, their growth forms, the climate they live in and the associations they have with other plants to come up with a picture of the past. Just as fossil animals can show us how that type of animal has evolved through time, plants show evolution and reflect a changing climate.

27. Present day scene: John Day Fossil Beds in Oregon is one of the worlds most complete fossil records and is an excellent example of how climate and life change through time. It is unique because the fossils found there span a vast amount of geologic time, nearly 40 million years. There are four distinct layers, or formations that represent life that existed at different points in time.

28. Clarno Formation 48 to 35 m.y.a.: 48 to 35 million years ago this area (now in eastern Oregon) was closer to the coast and was covered with "paratropical" evergreen forests. (Paratropical: between tropical and subtropical).

29. Fossils: We know of these forests because of the splendid sample of fossil seeds, nuts, fruits, leaves, branches, and roots. The Clarno locality is one of the finest fossil plant localities on the planet, with hundreds of species, many new to science, preserved. The Nutbeds were formed as a delta in a lake. Because of the variety of plants fossilized we have a very detailed look at the ancient environment and make assumptions about the climate.

30. John Day Formation: By 32 million years ago the climate had become cooler, a warm temperate climate with deciduous forests. This formation spans more than 20 million years and more than 120 species of mammals have been found in it, including the "rhinoceros" (Diceratherium) seen in the center of the slide, Miohippus (a three toed horse), Sabre toothed "tigers" (one is seen in the tree) and early "dog" Mesocyon.

31. Mesocyon: this early dog, a mesocyon, was identified by the teeth and features of the skull that are similar to modern day members of the dog family.

32. Metasequoia: The metasequoia, or Dawn Redwood, grew in the ancient forests. It is in the same family as the redwoods that grow today in California and Oregon. For years it was considered to be an extinct species but living trees were discovered in China.

33. The Mascail Formation dates from about 15 million years ago. The ash deposits and erosional outwash materials that became the Mascall Formation were from the Strawberry Volcanoes that stood to the south at that time. Lush grasslands and hardwood forests, similar to the eastern U.S., were home to a great variety of animals that we might recognize as horses, camels and deer as well as bears, weasels, dogs,

and cats.

34. The Merychippus was a pony
like horse. This one was caught up in the volcanic eruptions and buried quickly enough that it was preserved as a fossil rather than rotting away.

35. Rattlesnake Formation: The Rattlesnake Formation represents the Miocene epoch, and dates from 7 to 5 million years ago. The populations had adjusted to a significantly dryer, cooler climate. Grasses were more abundant than shrubs and trees, and grazers were more abundant than browsers. Pictured here are; pliohippus (in the modern lineage of the horse), dog, short face bear, peccaries, and tetralophodon (in the elephant family).

36. Florissant: Florissant Fossil Beds in Colorado provides another unique look at an ancient environment because of the abundance of very detailed plant and insect fossils dating from nearly 35 million years ago.

37. Stump: In addition to the detailed carbon fossils, there are huge petrified remains of redwood trees. We can look at these petrified stumps and draw two different conclusions. Either the climate was the same back then as it is in modern day Colorado and redwood trees back then had very different requirements than the ones today do or.....

38. Redwoods: we can infer that the ancient redwoods had similar needs as the present day redwoods do; moderate climate and lots of moisture. The carbon fossils of plants and insects are also similar to modern day plants and insects that live in very warm humid climates and Florissant gives us a detailed look at how changing climate affects vegetation.

39. Pond: Trees and plants that grew next to the lake dropped leaves, twigs and branches into water where they were covered with volcanic ash and fossilized. The ancient winds of the Florissant region carried pollen that also fell into the lake and became fossilized.

40. Pollen: Because of the very detailed fossils that were formed at Florissant we can see this fossil pollen (if we use a microscope). Because each kind of plant has its own, unique shape of pollen, like a fingerprint, and because pollen can be carried for great distances by the wind, the fossil pollen gives a look at the vegetation of the entire region 35 million years ago.

41. Life Zones of Colorado: Today Colorado has several different life zones which are dependent on altitude, and it appears the same was true of the area in ancient times, with the valley floor being very lush, covered with redwood forests and the drier sites above the valley' were more similar to northern Mexico.

42. Daemonelix: Sometimes there are mysteries of the past that take years to solve. Sometimes a new or unique approach is used to figure them out, or sometimes they are never solved. These Daemonelix, or Devil's Corkscrews, as they were called, were a devil ova thing to figure out for the paleontologists who were studying the fossils of Agate Fossil Beds. Originally they were thought to be the filled in holes of ancient plant roots. Then, bones of paleocastor were found at the bottom of one, proving they were the trace fossils of this animal's activities. Paleocastor is an ancestral beaver that was

land oriented rather than water oriented.

43. Prairie Dog: The lifestyle of Paleocastor was similar to tine' prairie dog, except that it had a unique, spiraling burrow. Some of these burrows were filled with sediment and turned into trace fossils.

44. Dinosaur National Monument. This is a scene from Dinosaur National Monument. For a number of years visitors could watch paleontologists at work, removing surrounding rock from dinosaur fossils. At this point, they are no longer removing any more material from the quarry walls as so much evidence is present in the rocks surrounding the bones.

45. Although Dinosaur National Monument is best known for its large dinosaurs, a great effort is being made to understand the complete ecosystem of the Jurassic Morrison Formation. Mammals, amphibians, plants, sediments and trackways are all being studied, and information from them is used to yield a more complete picture of the past. (Trackways are the preserved footprints of animals and are considered trace fossils.)

46. Old Dig Site: The situation at Dinosaur National Monument is representative of the ways that new techniques are used to study the past. The science of Paleontology is an evolving science and has changed greatly in the past century.

47. Dinosaur Scene: As new techniques are discovered they change the way we look at fossils and the way we recreate the past.

48. NPS Symbol: The National Park Service continues to be a leader in using these techniques to better understand our past and, through protection of these world class fossils sites, preserves them for future generations to study and learn from.

Park Visit:

Visit a National Park Service site where fossils are found. Ask the Ranger:
What clues are found in the fossils?
How do they interpret them?
How do they reconstruct the ancient environment?
What excavation techniques do they use?
Any special techniques used to study the fossils?

Table of Contents

Our Changing Earth

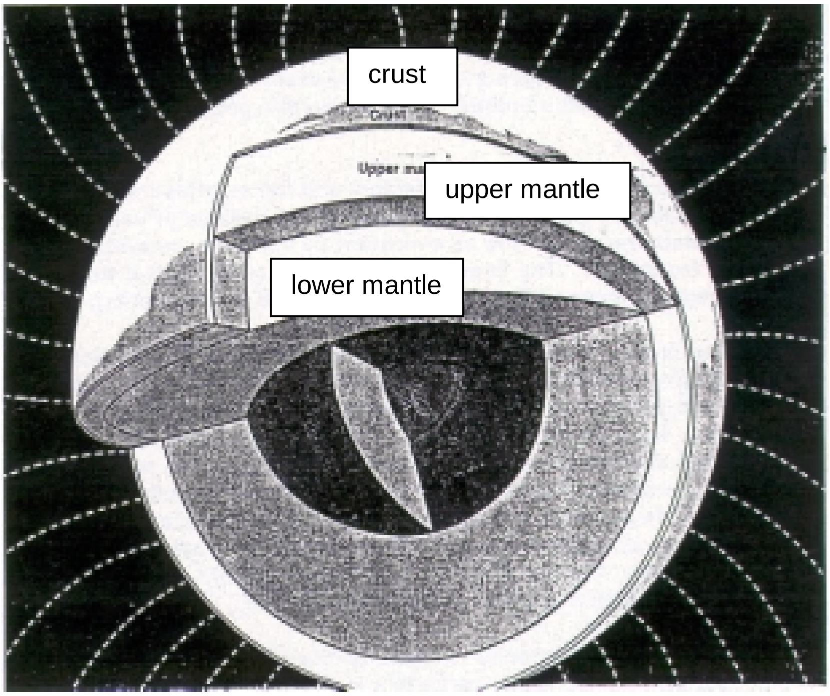
Teacher's Introduction

When we study fossils and use them as clues in reconstructing an ancient environment, the overwhelming realization is how much our earth has changed. Areas of our world that were once tropical, lush jungles near sea level are now arid, high plains. What were once the bottoms of oceans are now the top of sky piercing mountains. Once we make these discoveries, the question that comes to mind is "How?". This unit will introduce students to the theories that attempt to explain these tremendous changes. In the previous unit we learned how theories are formed from observations and how we use the present as a key to the past. The previous unit also examined the everyday, immediate environmental influences on animals and plants and explained how that affected their evolution and adaptations. This unit will take these skills a step further to examine the powerful earth forces that have had a broader effect on earth's geography, climate and life forms.

We will also look at some of the factors and forces affecting fossils. These remains of ancient life have survived for millions of years, yet can be destroyed in as little as an instant by improper excavation and storage techniques. The knowledge they offer can be lost if they are destroyed, or removed from context, or exposed to weathering.

Plate Tectonics: Geophysicists (scientists who study the physics of our changing earth) have developed a theory, plate tectonics, that explains in part the ever changing nature of our home, Earth. Tectonics, from the Greek meaning "builder", is the study of movement and deformation of the earth's crust. We can apply this theory to understand some of the factors that have contributed to the change of life on earth through time, as evidenced by the fossil record. Just as fossils tell a story of life, rocks tell a story of the changing earth. We can listen to that story by applying some basic geologic principles and using our eyes and senses.

The theory of plate tectonics is based on our observations, (made for the most part from or near the earth's surface), of the inner structure of the earth. The earth is made up of three layers. The outermost layer is the crust. The earth we see around us is the outermost part of the crust, which varies in thickness. The thinnest part is under the ocean floors, from 4- 7 km (2.7 4.3 miles). Under the continents the crust varies in thickness, with the crust beneath some mountains up to 70 km thick (about 44 miles). The average thickness of the crust beneath the continents is 35 km (22 miles). The next layer down is the mantle. The mantle is about 2,880 km thick (1800 miles) and is made up of three regions. The outermost is solid and lies below the crust. The center part is semi
molten and is also called the asthenosphere. The innermost portion is solid and under very high pressure. The core is the center portion of the earth. It is composed of two regions: the inner core which is solid and has a radius of 1,200 km (750 miles) and the outer core which is molten and about 2,240 km (1400 miles) thick.



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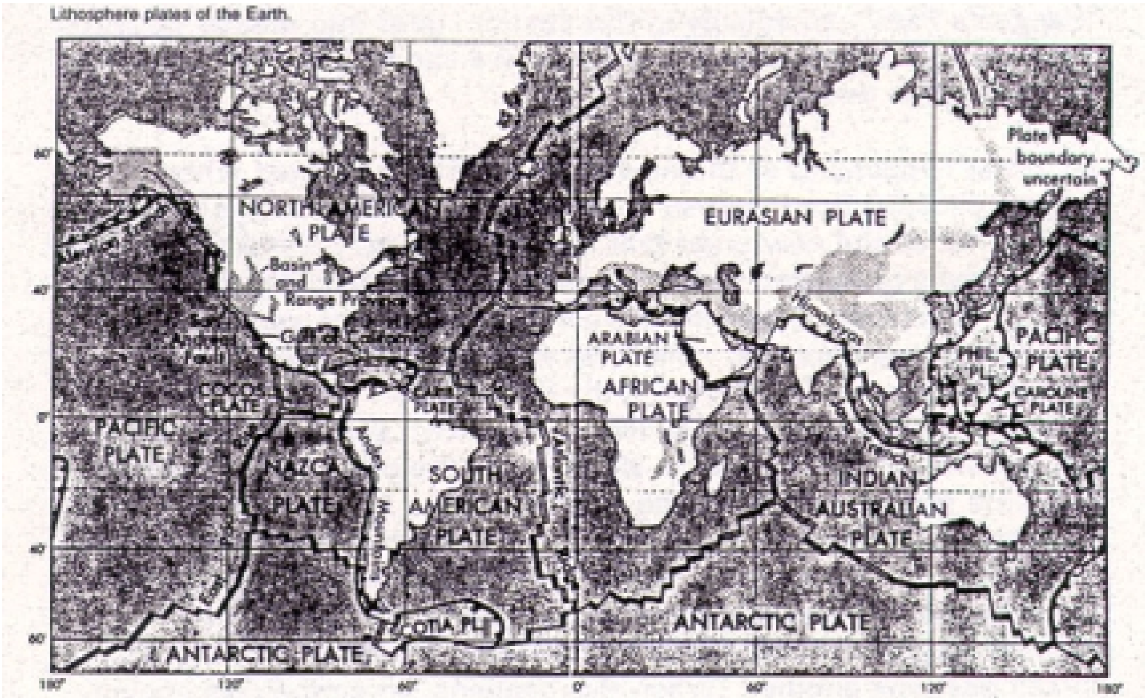
Together, the crust and the rigid outer layer of the mantle are called the lithosphere (Greek; lithos means rock). The lithosphere is not continuous or one solid layer. It is made up of about 7 large sections, or "plates" and about 13 smaller plates. These plates fit together like the pieces of a jigsaw puzzle. The plates are resting on the underlying layer, the asthenosphere, made up of the central layer of the mantle. The part of the mantle that the lithosphere rests on is made up of solid rock, but the rock is very hot (up to 3,000 degrees Celsius) and under great pressure. Experiments have shown that rocks subjected to very high pressure begin to flow like a thick liquid. So, the plates are actually floating on the semi liquid, central portion of the mantle. The tremendous temperatures at the earth's interior create convection currents from the interior flowing out to the surface, and these currents are the force that drives plate tectonics.

In most places the crust stops the escape of heat, but in places the crust is thinner and the heat escapes. Volcanoes are an example of heat and molten rock escaping, and the mid-ocean ridge is another.

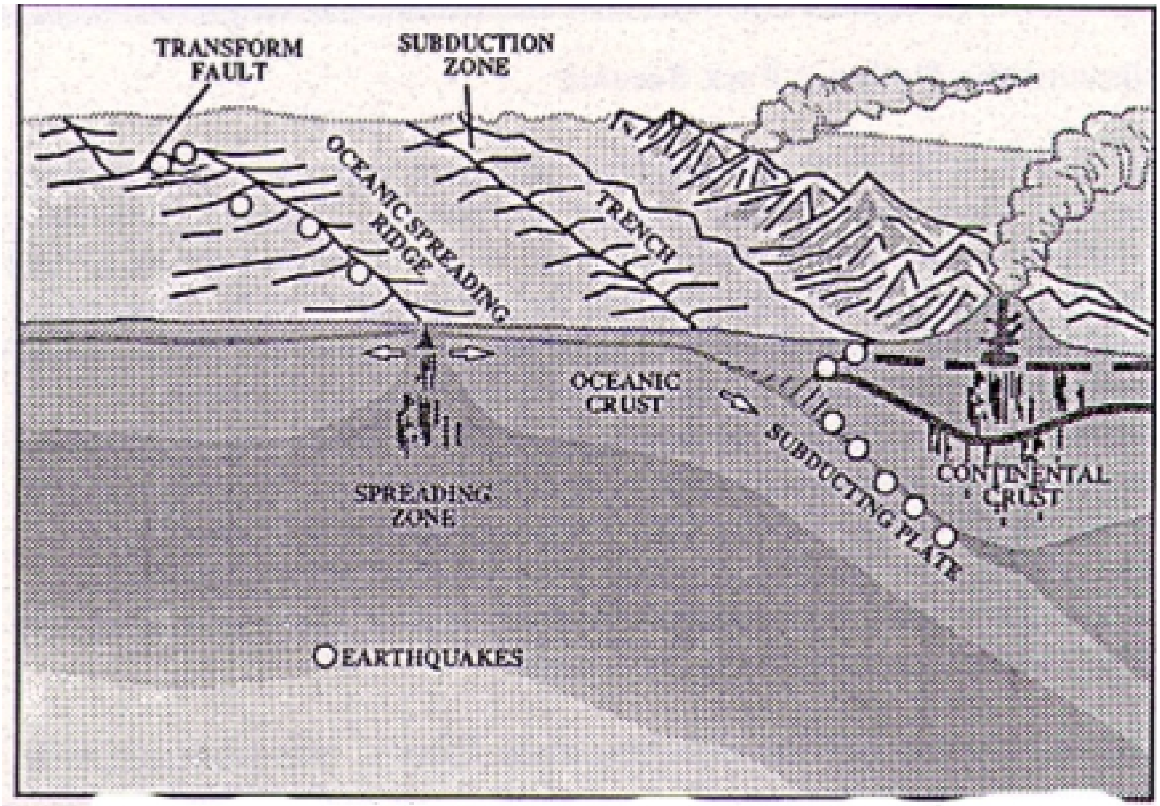


The mid-ocean ridge is a series of huge mountain ranges that extend along the floor of the oceans. It is the largest system of mountains on the planet, with the mountain ranges interconnected like the seams of a baseball. As molten rock escapes from the mid-ocean ridge, it cools and hardens, adding to the crust at each side of the ridge. This creation of new crust results from sea floor spreading, in which rocks on either side of the ridge slowly move apart in opposite directions, with two separate plates being formed at the spreading center. This theory is validated by dating the rocks on the ocean floor. Samples taken from the mid-ocean ridge are the youngest and age increases with the distance from the ridge.

The tectonic plates slowly move from the force of the convection currents and from the creation of new crust. Continental drift is the name that is used to describe the movement of the plates, or continents. These plates can be likened to a conveyor belt, carrying continents as well as volcanic islands and coral reefs. The North American plate is slowly moving at the rate of about an inch per year. "Pangea's Path", an activity in this section, goes into greater detail on the theory of continental drift and how we can map the movements of the continents through time.

So, what happens to all the new sea floor that is created when magma escapes from the mid-ocean ridge? Our earth stays the same size, so for all the new crust that is created, some must be consumed. This appears to happen at certain plate boundaries, called subduction zones. Subduction zones are all found under the sea and are also called deep sea trenches. The most well known of these is the Marianas Trench. This trench is the deepest part of the ocean, plunging down nearly 7 miles deep. When two plates move towards one another, one of the plates slides under the other, and is forced back into the hot interior of the earth's center. If you slide one piece of paper under another, the pieces move smoothly, because the paper is smooth. But because the plates are made of hard, jagged rocks, the plates don't move smoothly during subduction. The plates become caught and stuck until the pressure builds up and they are forced past one another. When this happens, an earthquake occurs.

When the subducting plate is forced back into the interior of the earth, the tremendous heat begins to melt the rock, turning it to magma. Some of this magma rises through thin places in the crust, and as it rises to the surface it forms a volcano. The activity " When Worlds Collide" allows students to see for themselves the tremendous forces unleashed when plates collide.



Accreted terranes and the growth of continental margins are also results of the subduction of one plate under another. Using the analogy of a conveyor belt carrying the continents, volcanic islands and coral reefs along is a good way to visualize this process. When the conveyor belt subducts under another plate the "things" that it carries are jammed up against the plate, adding, or accreting, to it. A good portion of the western United States and most of Alaska was assembled in this way.

Most volcanoes and earthquakes are found near subduction zones, with earthquakes also occurring near a type of plate boundary called a transform fault. Transform faults result from two convergent plates sliding past one another in opposite directions. As with subduction zones, the plates don't slide smoothly but become caught, until the pressure becomes so great that they release suddenly and cause an earthquake. The San Andreas fault is an excellent, and destructive, example of this situation.

The theory of plate tectonics and continental drift help us to understand the earth's phenomena, like mountains, earthquakes, and volcanoes. Also, the theory allows us to make sense of some of the mysteries of fossils. Changing climates, the discovery of the same species of fossils found oceans apart, and fossilized sea creatures found at the tops of the highest mountains in the world are all explained by this amazing theory.

Fossils and the National Park Service

So far in this unit we have examined some of the slow, tremendous forces that have molded and shaped our planet. These forces have been acting on the world around us for millions, even billions of years, and in part were responsible for the formation of fossils. However, the natural forces that created fossils can also destroy them. Fossils can survive for millions of years as long as they are buried underground. But once they become exposed, because of the erosion of the overlying, protective layers, they are subject to physical and chemical weathering. These forces can destroy them relatively quickly, along with the information they contain about the past. While the term "petrified" seems to imply that a fossil is strong and durable, fossils are actually quite fragile.

Natural factors are not the only threat to fossils. We humans, who have so much to learn from them, can damage and destroy fossils and their clues to our collective past, without realizing the extent of our actions. An objective of this unit is to increase awareness of the impact that we can have on fossil resources, and also increase awareness of the role that the National Park Service plays in preserving and protecting these keys to our past.

Unfortunately, there is a long history of destruction and exploitation of fossils. When settlers first began living on this continent, it seemed that the wilderness was endless. As they moved westward, day to day life was a struggle against the elements and the wild. Needless to say, preserving the natural ecosystem or fossil resources they encountered was not a top priority to them. Entire ecosystems and species were destroyed, some to the point of extinction, and many clues to the past were damaged or lost. An early account of the Florissant Valley, in central Colorado, written by a European settler, says that there was so much petrified wood lying on the surface of the ground that it was nearly impassable. Once the fossil wonders of the valley were publicized, souvenir hunters came in droves, and a number of commercial operations sprang up, charging a fee to haul off fossils and petrified wood. A visit to the site today shows very little petrified wood on the surface and only the huge stumps that were buried underground still remain. Other fossil sites in the country suffered similar fates.

In the 19th Century, certain progressive thinkers began contemplating the immense changes that had occurred in the American Landscape. "Transcendentalists" as they were called, like Henry David Thoreau and Ralph Waldo Emerson had an appreciation of the landscape on the intellectual level and felt spots of beauty should belong to all mankind. They were the first to bring up the idea of preserving parts of wilderness for future generations. John Muir began arousing the public to the fact that most of the true wilderness had vanished and people began to consider the intrinsic value that wilderness holds for us.

People like Thoreau and Muir were a different sort of pioneer. They helped the American public to look beyond the monetary value that an area held, in the form of grazing, mining, timber cutting, or the sale of fossils, to see that the natural beauty and wildness could offer something to the soul.

This change in attitude came at a time when Americans were looking for something to give them a sense of national pride. Many Americans of the time felt their nation to be lacking in comparison to Europe's long history of culture and sophistication. The scenic wonders of the western U.S. were something to marvel at, even for jaded Europeans, and gave Americans the beginnings of the national identity they were longing for.

The first National Parks were set aside as a result of these national concerns and in 1916 the National Park Service was created to acquire and manage the parks. Congress gave the National Park Service a dual mandate: to conserve park resources and also to make them available for public enjoyment. They were to meet these two mandates in such a way as to keep the resources unimpaired for future generations.

This dual mandate has proved difficult to meet at times. In the early days, the public enjoyment aspect was favored. Bears were fed as a tourist attraction and predators like wolves and cougars were killed so visitors would see more "good" animals like deer. There was no knowledge of what the long term results would be or how these actions would affect entire ecosystems. These actions reflected the prevailing public attitudes at the time and the policies of the National Park Service have evolved as have public attitudes.

As the National Park Service has evolved, education has proven to be the key to meeting both aspects of the Service's mandate in a satisfactory way. Fossil Parks are an excellent example of how education and enjoyment can lead to protection. Few people come to the fossil parks with an understanding of the unique geologic processes that led to fossil formation or the ways that the context of the fossils shows us a picture of the past. Once they have visited the park and learned about it through programs, activities, exhibits and trails, visitors have an appreciation for the area and the fossils, and are much less likely to want to take fossils home with them or to behave in ways that could prove detrimental to the fossils. The research conducted by Park Staff plays a large role in presenting an updated story of the past that reflects the ongoing efforts to better understand the amazing story of our earth.

Unit Goals and Objectives

Goal: Students will achieve an understanding of the larger forces which affect the changing nature of our planet.
Objectives: Students will identify a theory, plate tectonics, that explains, in part, the changing nature of our planet.
Students will describe the basic principles of plate tectonics.
Students will relate location of earthquakes and volcanic eruptions to plate tectonics.
Students will describe an ancient landmass, Pangea, and explain the theory of continental drift.
Goal: Students will gain an appreciation of the role that the NPS plays in the protection of fossil resources.
Objectives:
Students will identify causes and consequences of fossil loss.
Students will explain the role the NPS plays in fossil protection.

Sources for Further Information

<u>This Dynamic Planet: World Man of Volcanoes, Earthquakes and Plate Tectonics</u> This map is highly recommended as a classroom aid for understanding the theory of plate tectonics and its effects. It is available for a minimal cost ($1.50 for teachers, $3.00 for

others) and can be obtained by writing to the U.S.G.S., Map Distribution, Box 25286, Federal Center, Denver CO, 80225. Make your check payable to Dept. of the Interior, U.S.G.S. There is no charge for postage. In addition to the map, there are two free publications, Our Changing Continent and Earthquakes, which are available by writing to the same address.

The Amateur Geologist: Explorations and Investigations. Raymond Wiggers, An Amateur Science Series Book. This book presents projects and activities that explore many aspects of the science of geology. Published by the author, 1993, ISBN 0-531-11112-1

Earth: The Everchanging Planet, by Donald M. Silver, Ph.D., illustrated by Patricia J. Wynne. A wonderfully illustrated survey of the earth, describing how it was formed, including information on different types of rocks, weathering and erosion, the formation of mountains and plate tectonics. ISBN 0-394-89195-3

Volcanoes and Earthquakes, part of the Usborne "Understanding Geography" series. This book is written for students aged 11 to 14 and does an excellent job of describing the causes and effects of earthquakes and volcanoes.

Oh, Ranger, by Horace M. Albright and Frank J. Taylor. 1986 OUTBOOKS, 217 Kimball Ave., Golden CO, ISBN 0-89646-068-1

First published in 1928, this book was written by a man who, as Acting Director, organized the National Park Service when it was established and went on to become the first Superintendent of Yellowstone National Park and the second Director of the National Park Service. The combination of amusing anecdotes, information and narration make it enjoyable for readers of nearly all ages. Because of the intertwining of history and nature the book can be part of an interdisciplinary assignment.

Resources for Instructors:

The Practical Paleontologist, Steve Parker, Simon and Schuster/Fireside, NY, NY, Copyright 1990 by Quarto Publishing.
ISBN 0-671-69307-7

The Story of the Earth, ISBN 0-565-01113-8
Earthquakes ISBN 0-118-84066-5
Volcanoes ISBN 0-565-01048-4
This is an excellent series published by the British Museum of Natural History Publications, Cromwell Rd., London SW7 5BD

National Parks. The American Experience, by Alfred Runte. 1987, University of Nebraska Press, ISBN 0-8032-8923-5
Written by a leading authority on national park history and management, this book provides an understanding of the origins, development and future of the National Parks.

Adventures of a Nature Guide, by Enos Mills. The New Past Press, Inc. Friendship, Wisconsin, ISBN 0-938627-12-0
Written by a man who was an associate of John Muir and is considered the founder of nature interpretation, this book provides an historic look at the emergence of advocacy

for wilderness and the National Park Service ideal.

Vocabulary

Latitude: The distance north or south of the equator, measured in degrees.
Longitude: Angular distance east or west on the earth's surface, measured in degrees up to 180. Measured by the angle the meridian or line makes with the prime meridian, usually the one passing through Greenwich, England.
Continental Drift: The theory that continents have moved in relation to one another.

Seismology: The study of earthquakes.
Plate (Tectonics): A large section of the lithosphere that floats on the underlying, softer asthenosphere and moves independently of other plates.
Core: The center portion of the earth. It is thought to be composed of two regions: 1) the inner core which is solid and has a radius of 750 miles; and 2) the outer core which is molten and about 1400 miles thick.
Mantle: The zone of the earth's interior between the crust and the core. The mantle is about 1800 miles thick and is made up of three regions. The outer most is solid and lies below the crust. The center part is molten and is also called the asthenosphere. The innermost portion is solid and under very high pressure.
Crust: The outer most layer or shell of the earth. It varies in thickness from 3 to 30 miles, yet is less than 1% of the earth's total volume.
Lithosphere: The outer zone of the earth. It is relatively rigid and includes the crust (oceanic and continental) and the outermost, solid part of the mantle.
Asthenosphere: The zone of the earth directly below the lithosphere which is believed to be soft and have a yielding, plastic flow. This zone is made up of the central layer of the mantle.
Pangea: A hypothetical "super" continent. It is believed that Pangea broke apart in the Mesozoic Era to form the present day continents.
Convergent Plate Boundary: Zone where two plates are moving toward one another.
Subduction Zone: The area in which one plate descends beneath another.
Mid-oceanic Ridge: A huge mountain range that is on the ocean floor.

Fault: A break in the earth's crust.

Classroom Activities
Classroom Activity 1

Model of the Earth

Objective: Students will use given measurements and scale to construct a cross section of the earth, labeling crust, mantle and components, core, lithosphere and asthenosphere. This exercise and the follow up discussion will illustrate the basic structure, crucial to understanding plate tectonics.

Materials:
Model of the Earth handout and vocabulary words
compass and ruler
pencil and paper
list of measurements,
scale and definitions

Background: Together, the crust and the rigid outer layer of the mantle are called the lithosphere (Greek; lithos means rock). The lithosphere is not continuous or one solid layer. It is made up of about 7 large sections, or "plates," and about 13 smaller plates. These plates fit together like the pieces of a jigsaw puzzle. The continents are parts of these plates. The plates are resting on the underlying layer, the asthenosphere, made up of the central layer of the mantle. The part of the mantle that the lithosphere rests on is made up of solid rock, but the rock is very hot (up to 3,000 degrees Celsius) and under great pressure. Experiments have shown that rocks subjected to very high pressure begin to flow like a thick liquid. So, the plates are actually floating on the semi liquid, central part of the mantle. The tremendous temperatures at the earth's interior create convection currents, the forces that are believed to drive plate tectonics. Heat rises and since the exterior of the earth is cooler, heat flows out to the surface and creates currents that slowly move the plates. A demonstration of this is easily shown by heating a broad pan of water on a burner and placing flat pieces of balsa wood, or thin sheets of any wood on the surface. As convection currents are created by the heat, students can observe the woods increasing mobility.

Procedure: Pass out copies of the handout.

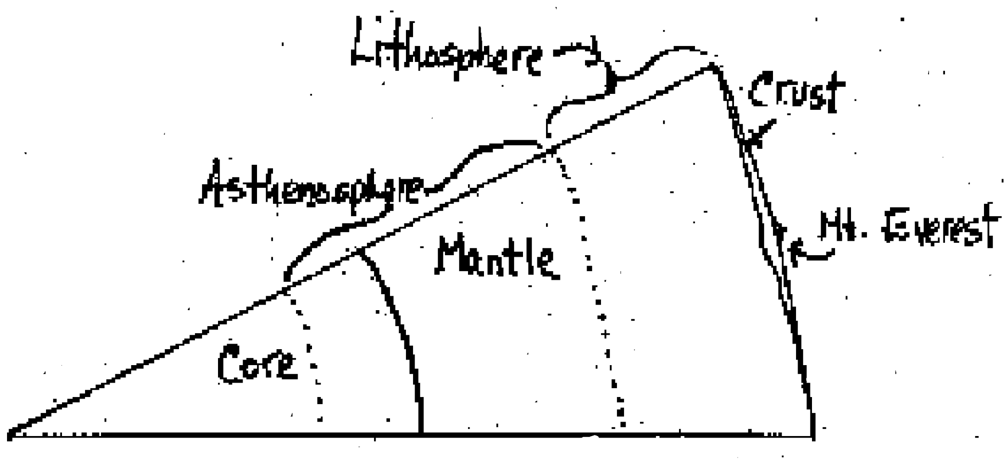
Follow Up: Discuss the possible consequences of the rigid lithosphere resting on the softer, semi-liquid asthenosphere. A pool cover rests on top of a pool and floats. What if, instead of a pool cover all one piece, the top of a pool is covered with several large rafts? These large rafts would correspond to the plates, large segments of crust that float and move independently.

A Model of the Earth Handout

When one begins to talk about "size" in geology, it soon becomes obvious how important one's perspective is. A blade of grass is pretty small almost inconsequential to a human, but it's pretty big to an ant, and even a whole universe to a bacteria that lives on it. How big something is really depends on who is looking at it.

That's one of the points this exercise is intended to remind you of. For most of us, mountains seem to be pretty big things. But in comparison to the whole earth, how "big" is a mountain? One way to answer that question is to look up numbers. You can find out the diameter of the earth, the radius of the inner core, the mantle, the asthenosphere and the lithosphere, the thickness of the crust and the height of the tallest mountain and depth of the deepest sea trenches by looking at your vocabulary words and in encyclopedias or geology books.

But listing these numbers next to each other still may not mean very much. A much better way to compare these numbers and get a better understanding of the structure of the earth is to draw a picture. Construct a diagram of the earth, from the very center to the outer surface. On the surface draw in any mountains or ocean features you have researched. You can make any kind of drawing you would like but it could look something like the one shown here. The most important thing to remember is that everything should be drawn to scale.



How does your model of the earth fit together with the theory of plate tectonics?

What is the driving force behind plate tectonics and continental drift?

Classroom Activity 2
Old Neighbors

Objectives: This activity will introduce students to the theory of continental drift, the evidence used to support the theory and the concept of an ancient super continent, Pangea.

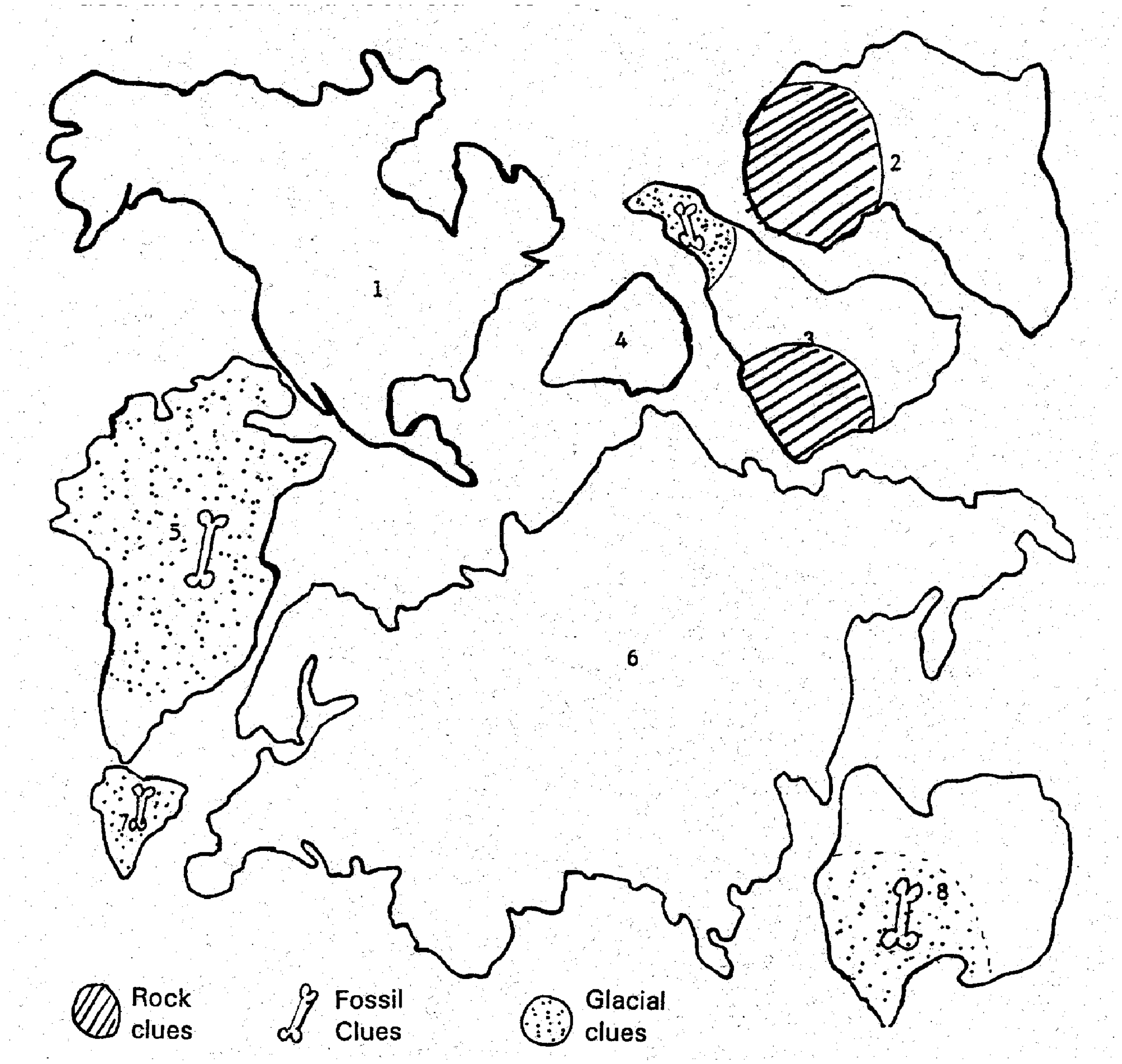
Background: Look at a map of the world. Do you see places where the continental boundaries might fit together like pieces of a puzzle? Back in the early part of the century, during the 1920's, a meteorologist named Alfred Wegener noticed the similarities in shapes and showed how all the continents could fit together. Because of this and other evidence he proposed that all of the continents had once been joined into one huge continent that he named Pangea. One of the pieces of evidence that he used to support this theory was the fact that the same types of fossils had been found in South America, Africa, South East Asia, Australia, and Antarctica, suggesting that they had all been joined at one time. Also, geologists had found that rocks on all of these continents, in the same regions as the fossils, bore evidence of glaciation. And, it was discovered that the exact same type of rock, of the same age, were found in both South America and Africa. All of these clues led him to deduce that the continents had been joined and had broken apart. Few people believed in his theory since evidence of plate tectonics hadn't been discovered yet and there was no explanation for HOW the continents had moved.

The mid-ocean ridge is a series of huge mountain ranges that extend along the floor of the oceans. It is the largest system of mountains on the planet, with the mountain ranges interconnected like the seams of a baseball. As molten rock escapes from the mid ocean ridge, it cools and hardens, adding to the crust at each side of the ridge. This creation of new crust is called sea floor spreading. The theory is validated by dating the rocks on the ocean floor. Samples taken from the mid ocean ridge are the youngest and age increases with the distance from the ridge. No rocks on the ocean floor are older than 200 million years and it is deduced that the breaking apart of the continents occurred about that time.

Directions: Pass out copies of the "Old Neighbors" handout and discuss the background material.

Old Neighbors

Look at a present day map of the world and use it as a key to name each of the continents drawn below. Cut out these continents after you have named them and try to fit them together like the pieces of a puzzle. Use the continent of Africa as the center of your puzzle, and use the fossil and rock clues to help you put Pangea back together again.



What clues led Wegener to believe in an ancient super continent?

What do we call this super continent?

What caused the continents to move?

What do we call the movement of the continents?

Classroom Activity 3
Pangea's Path

Objectives: In this group activity students will learn about the concept of sea floor spreading. Using the rate of sea floor spreading, they will calculate the rate of continental drift. They will utilize math and geography skills to plot the movement of a drifting continent, North America, through time. They will identify the position of the continent at a given time using latitude and longitude. They will match that latitude and longitude to a geographical spot and research present day climate of that spot. They will then contrast the present day climate with the original position of the continent.

Background: The mid-ocean ridge is a series of huge mountain ranges that extend along the floor of the oceans. It is the largest system of mountains on the planet, with the mountain ranges interconnected like the seams of a baseball. Look at an atlas or map and identify the mid-ocean ridge. As magma (molten rock) escapes from the mid ocean ridge, it cools and hardens, adding to the crust at each side of the ridge. This addition of new crust to the ocean floor is called sea floor spreading. The theory is proved by dating the rocks on the ocean floor. Rocks right at the mid-ocean ridge are the youngest; the further the rocks are from the mid-ocean ridge, the older they are. No rocks on the ocean floor are older than 200 million years. The continents slowly move from the force of the convection currents and from the creation of new crust. The North American plate is slowly moving at the rate of about an inch per year.

Materials:
information given in the directions
calculator
world map

Directions: North America has been moving northwestward at the rate of about an inch per year. Figure out how far it has come in the past 200 million years by using the following information; there are 5,280 feet per mile and 200 million is expressed mathematically as 200,000,000 (2 x 10 8th). Once you have figured out how far the continent has moved, find where you live on the map and figure out approximately where it was 200 million years ago, using latitude and longitude. Look on the map and see what exists now at that longitude and latitude. What is the climate like at that spot? How does it compare to the climate where you live now?

Classroom Activity 4
When Worlds Collide

Objectives: Students will determine the effect of convergent plates and relate volcanic activity and earthquakes to convergent plate boundaries.

Background: What happens to all the new sea floor that is created when magma escapes from the mid-ocean ridge? Our earth stays the same size, so for all the new crust that is created, some must be destroyed. This appears to happen where plates meet, called convergent plate boundaries. When two plates move towards one another, one of the plates slides under the other, and is forced back into the hot interior of the earth's center. These places where one plate is forced under another are called subduction zones. Subduction zones are all found under the sea and are also called deep sea trenches. The most well known of these is the Marianas Trench. This trench is the deepest part of the ocean, plunging down nearly 7 miles deep. Look at a map or atlas and locate the deep sea trenches or subduction zones.

What causes earthquakes? If you slide one piece of paper under another, the pieces move smoothly, because the paper is smoothed But tectonic plates are made up of hard, jagged rocks and when one plate slides under another at a subduction zone, the plates don't move smoothly. The plates become caught and stuck until the pressure builds up and they are forced past one another. When this happens, an earthquake occurs.

What about volcanoes? When the subducting plate is forced back into the interior of the earth, the tremendous heat begins to melt the rock, turning it to magma. Some of this magma rises through thin places in the crust, and as it rises to the surface it forms a volcano. Most volcanoes are found near subduction zones.

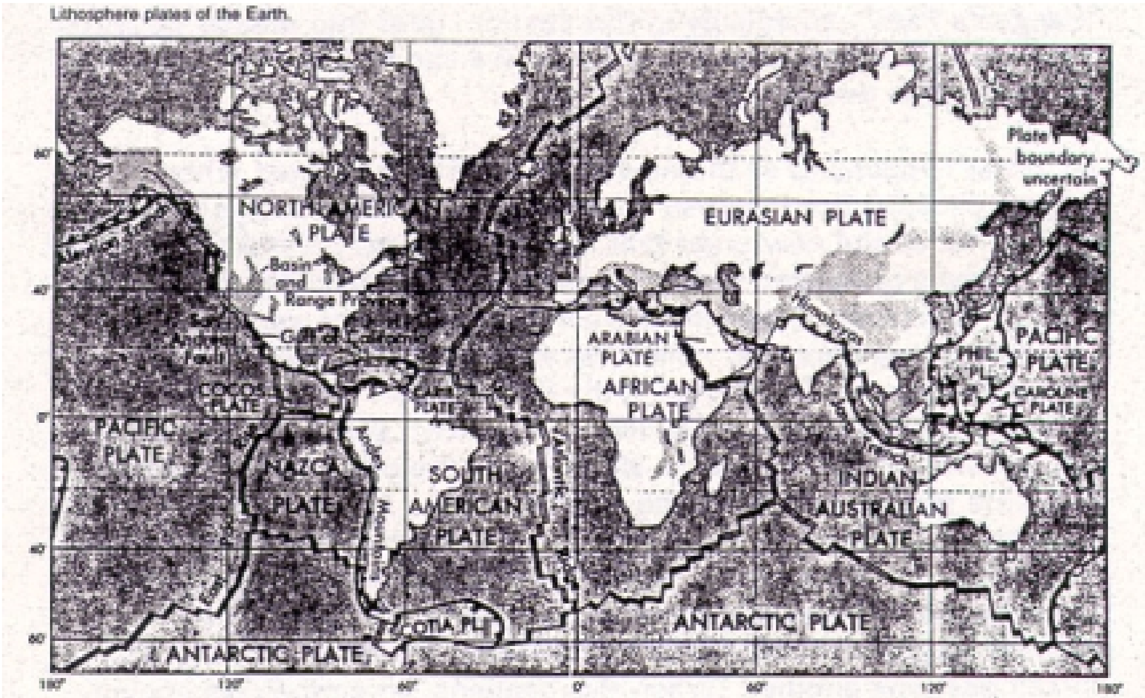
Directions: Pass out copies of the handout "When Worlds Collide" on the next page and a copy of a world map. Have the students, or teams of students, locate the sites of the volcanic eruptions and earthquakes and relate them to plate boundaries.

When Worlds Collide

Directions: Mark the locations of the volcanic eruptions and earthquakes on the world map.

Volcanic Eruptions	Earthquakes
5000 B.C. Mt. Mazama, Oregon, U.S.	1456 Naples, Italy
1631 A.D. Mt. Vesuvius Italy	1737 Calcutta, India
1831 Mt. Mayon, Sumbawa Island	1797 Quito, Ecuador
1883 Mt. Krakatoa, Indonesia	1847 Zenkoji, Japan
1902 Mt. Pelee, Martinique, West Indies	1868 Peru and Ecuador
1912 Katmai, Alaska, U.S.	1906 San Francisco
1928 Mt. Etna, Italy	1908 Messina, Italy
1943 Paracutin, Mexico	1923 Tokyo, Japan
1953 Mt. Spurr, Alaska, U.S.	1939 Chile and Turkey
1966 Mt. Redoubt, Alaska, U.S.	1953 N.W. Turkey
1975 Mauna Loa, Hawaii, U.S.	1957 Northern Iran
1980 Mt. St. Helens, Washington, U.S.	1960 Chile and Morocco
1982 El Chichon, Mexico	1976 Guatemala
1992 Mt. Pinatubo, Phillipines	1994 Los Angeles

How do the locations of the earthquakes and volcanoes relate to plate boundaries and subduction zones?



Follow up: Florissant Fossil Beds National Monument, in central Colorado, records thousands of volcanic eruptions in the geologic record found there. There are many other places in Colorado where traces of volcanic activity are recorded, some as recent as 12 million years ago. From what we have learned about plate tectonics, it doesn't make sense. Some scientists think that the reason that volcanoes occurred there is because pieces of a subducting plate broke off and were carried eastward to the area under present day Colorado. Because of a weakness in the crust under what we now call Colorado, the piece of subducted plate came to the surface, producing volcanoes.

Classroom Activity 5
Making Mountains

Objectives: This simple demonstration shows three of the four types of mountain building processes.

Background: There are three kinds of mountains, each formed in different ways, but all three types are formed as a direct result of plate movement. Volcanic mountains are built up by lava that has escaped from the interior of the earth. As the lava cools, it forms igneous rocks and mountains are built up. **Volcanic** mountains form in a variety of places: where the plates are spreading apart (the mid-ocean ridge); near subduction zones (the Andes and Cascade ranges); and over hot spots (the Hawaiian Islands). **Fault Block** mountains like Grand Teton National Park and Great Basin National Park occur in places where the earth's crust has been broken into large blocks by faulting. When crustal movement occurs from plate tectonics, some of the blocks are lifted or tilted while others sink. The third type of mountains are called **folded** mountains. Examples of this type are the Appalachians and Himalayas. These ranges are formed by the collision of two plates. The force of the collision causes folding of weaker portions of the continental crust into arches and troughs.

Materials:
wax paper
rolling pin
dough ingredients: flour, cream of tarter, salt, oil, water

Procedure: Mix together 2 1/2 cups flour with 1 tablespoon cream of tarter and 1/2 cup salt. Divide the mixture in half (approximately). Add 1 cup boiling water, 20 drops food coloring, and 1 1/2 tablespoons oil to each (different colors to each batch). Mix well, then knead, adding flour as necessary to make a dough that is not at all sticky.

Demonstration: On separate pieces of wax paper roll out the two batches of colored dough into squarish shapes about 1/2 inch thick. These two pieces each represent a tectonic plate. Line up one edge of each piece of dough with the edge of the wax paper. These edges will be the convergent plate boundaries. Take the rolling pin and press down into one piece of dough, making a depression, or thinner line parallel to the "convergent" edge. This depression represents a weaker spot in the continental crust of that plate. With the two
edges next to one another, slowly push the two plate toward one another. As they collide, you may need to apply pressure to the plate boundary to prevent buckling. As the plates converge, the weak spot in the one plate will begin folding up and form a ridge, representing a range of folded mountains like the Appalachians.

To demonstrate the Fault Block mountain building process, roll out the dough on to two sheets, as in the demonstration for folded mountains. Before converging the two pieces of dough, cut one piece into many squarish pieces. These cuts represent faults in the earth's crust. As you push the pieces together, these blocks will crumple and shift, with some lifting higher than others.

Classroom Activity 6
Exploring Ethics

Objectives: This activity will foster discussion and decision making processes. In this exercise students are presented with a variety of situations and asked to consider the possible responses. They should be encouraged to discuss the factors that influenced their reactions.

Background: Discuss the role that the National Park Service plays in preserving and protecting fossils. The Service was created in 1916 to manage the Nation's unique areas, from historic sites to pristine wilderness to fossil deposits. At this time there are eight parks that are set aside specifically to protect world class fossil sites, and there are nearly 100 other Parks and National Monuments where fossils are found. When the Park Service was created it was given a dual mission: to preserve and protect the resources of the park area for present and <u>future</u> generations and to provide for the enjoyment of the visitors.

These two different goals can be very conflicting at times. Sometimes fossils are best protected if they are left underground, yet that means that no one can see them and enjoy them. Some visitors feel that the best way for them'to enjoy a fossil site is if they are allowed to dig and collect fossils. Also, it is very difficult for some visitors to understand how their actions add up. It might seem insignificant to take home a small piece of petrified wood, yet if every visitor took home such a piece it would result in tons and tons of wood being carried off every week! Because of the consequences of many individual actions and their job to preserve fossils for future generations, the Park Service has very strict rules that don't allow any collecting of fossils, of any type.

Other public land areas have different policies. In general, it is illegal to collect vertebrate fossils on any public lands unless the person has a special permit and is a trained scientist. In certain areas it is legal to collect invertebrate and plant fossils. Students should contact the agency that manages the land and find out what the policy is before doing any collecting.

What are the consequences if fossils are taken illegally? In addition to the fact that the person doing the collecting could face serious fines and time in jail, there are other, less personal consequences. It takes a trained person to dig fossils. Although the word petrified seems to connotate that a fossil is hard and durable, fossils can be very fragile, and at times are just fragments, loosely held together. Not using the proper techniques to excavate them can result in the fossil being destroyed. Also, it takes a trained person to understand the kind of information that needs to be recorded about a fossil and where it is found before it is collected. Without that information, the fossil will be "out of context" and much of the information about the past is lost.

If students are interested in learning more about paleontology and excavation techniques, they can contact a local university or museum to see if there are any volunteer programs or internships they could participate in. This opportunity would allow them to see how professional paleontologists work and learn more about paleontology.

Procedure: Divide students into small groups for discussion and give each group a copy of the situations they are to consider. Appoint one person to take down the responses. Ask them to consider each situation presented and come up with their reactions to the situations. After they have talked about their different responses, get together as a classroom and discuss the different responses.

Situation 1: You are visiting Florissant Fossil Beds National Monument. The ranger is leading your group on a guided walk. The group has stopped to look at a circular area on the ground that is covered with small pieces of petrified wood. These chips of wood are an indication of a huge petrified stump that is still buried under the ground. The ranger lets people in the group pick up some of the pieces to look at. When it is time to continue walking, you notice that your friend has put the piece she was holding into her pocket instead of on the ground. What do you do? Since its only one small piece, does it matter?

Situation 2: You are an amateur geologist, a rock hound out for the day looking for interesting rocks to identify. You discover some petrified bones sticking out of hillside. You are familiar with excavation techniques because you have read all about it in books. What would you do?

Situation 3: Your hobby is collecting fossils. Every time your family goes on vacation you go to privately owned places to collect fossils. You also like to visit National Park areas with fossils and learn about the fossils that are found there. A family has moved in next door that shares your interest in fossils and has a large collection. You are looking at their collection one day and see a beautiful piece of petrified wood. You ask where they found it and are told it came from the Petrified Forest National Park in Arizona. What would you say?

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Outdoor Activities
Outdoor Activity
Dance of the Continents

Background: Students should be familiar with continental drift, and consequences of colliding and subducting plates, including accreted terranes.

Directions: Divide students into groups of five and up. Each group is a tectonic plate. Have the groups spread out on a playing field, holding hands in rows. Call out various scenarios and the students move accordingly. Scenarios could be: sea floor spreading results in the continents moving apart, continental drift results in collisions. Collisions result in subduction, accreted terranes and volcanoes, and mountain building. Divergent movement along plate boundaries results in earthquakes.

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Slide Show Script

1. Title slide: This program will look at the tremendous forces that shape our earth and examine a theory that helps to explain how the geography of our planet has changed through time, in turn affecting climate and life. This theory is called plate tectonics. Tectonics, from the Greek meaning "builder" is the study of movement and deformation of the earth's crust.

2. Earth cross
section: The theory is based on our knowledge of the inner structure of the earth. The earth is composed of concentric layers, with the outermost zone, the lithosphere (made up of the crust and the outer portion of the mantle), being relatively rigid. The underlying layer is called the asthenosphere. It is softer and has a yielding, plastic quality.

3. Buoyancy: Because the lithosphere is less dense, it floats on the asthenosphere, like a boat.

4. Plates: Another quality of the lithosphere is that it is not one solid piece but is composed of more than a dozen pieces, called plates that fit together like the pieces of a jigsaw puzzle. These plates can move independently of one another and this movement is called continental drift.
(Their movement can be compared to a conveyor belt, with the plates carrying along

the continents, coral reefs, and volcanic islands.) The slow movement is powered by convection currents caused by the tremendous heat at the earth's center, and by the creation of new crust.

5. Mid-cean Ridge: New crust is created at the mid-ocean ridges. The mid-ocean ridge is a series of mountain ranges that extends along the floor of the oceans and it is also a series of plate boundaries, where molten magma from the interior of the earth can escape. As the magma escapes, it cools and creates the mountains that form the mid ocean ridge. For all the new crust that is created, some must be consumed. This happens at subduction zones, where plates are forced down into the inner recesses of the earth.

6. Sea Floor Spreading: The formation of new crust adds to the plates on either side of the mid-ocean ridge and results in sea floor spreading, in which the two plates slowly move apart. This slow spreading pushes on the "conveyor belt", moving along the plates and the continents they carry. The North American Plate is moving slowly northwestward at the rate of about 1 inch per year. Although this doesn't sound like very much, this process seems to have been in effect for the history of the earth, and over time has had a great effect on the movement and position of the continents. The colors on the map show the ages of the rocks that make up the ocean floor. The youngest rocks are those that are being formed at the mid-ocean ridge. As you move away from either side of the ridge, the rocks become progressively older because they formed earlier and have slowly moved away from the spreading center.

7. Map of World: Besides having an affect on the physical location of the continents, plate tectonics accounts for the major geological ~ features of our planet. This map shows some of the phenomena associated with subduction zones: volcanoes, earthquakes, and deep ocean trenches. When a plate subducts, the extremely hot temperatures of the inner earth cause it to melt and become magma.

8. Volcano Cross Section: The extreme amount of magma associated with subducting plates rises to the surface and escapes through weak spots in the earth's crust, forming volcanoes.

9. Mt. St. Helens: Mt. St. Helens is only one of the many volcanoes that make up the "Ring of Fire"; a series of volcanoes associated with the subducting plates of the Pacific Ocean.

10. Lava, Hawaii Volcanoes Nat. Park: Volcanoes also occur at "hot spots". Hot spots are believed to result from rising plumes of heat within the underlying mantle. The Hawaiian Islands are an example of volcanic islands that rest on oceanic crust and they trace the movement of the Pacific plate over a hot spot.

11. Haleakala Crater: The Islands were formed progressively as the oceanic crust moved over the hot spot and magma escaped to cool and form new land masses. Because of the progressive nature of this island formation, the Hawaiian Islands are consecutively older from southeast to the northwest.

12. Drawing: Earthquakes are another consequence of sea floor spreading and the resultant subduction. They stem from the sporadic shifting of the subducting plate. As the plate subducts, it doesn't slide under smoothly but becomes hung up until the pressure builds. Transform faults occur when two convergent plates slide past one

another in different directions.

13. Earthquake Damage: When the plate does finally move, the sudden release of energy causes an earthquake. This slide illustrates damage 'occuring from an earthquake along the San Andreas Fault, a transform fault.

14. Grand Teton Nat. Park: Volcanic mountains are only one type of mountain formed from plate movement. While they are formed by subduction, other mountain ranges are formed by the collision of plates. Fault block mountains, like these in Grand Teton National Park, occur in places where the earth's crust has been broken up into large blocks by faulting. When crustal movement occurs from plate tectonics, some of the blocks are lifted or tilted while others sink.

15. Shenandoah Nat. Park: Another type of mountain formed by plate collisions are folded mountains. Examples are the Appalachians and Himalayas. The force of the collision causes folding of weaker portions of the continental crust into arches and troughs. These mountain building processes explain how fossils of sea creatures can sometimes be found at the tops of mountains.

16. Storm Moving In: When our earth changes its physical appearance, the climate changes too. Climate is affected by many different factors, such as latitude, altitude, proximity to large bodies of water and mountain ranges, and global weather circulation patterns.

17. Winter Scene: Florissant Fossil Beds National Monument in Colorado is a case in point. Today Florissant lies at an elevation of over 8,000 feet and has a cool, dry climate. (The average temperature is 39 degrees F. and the average precipitation is 15 inches per year.) The predominant vegetation is Ponderosa Pine interspersed with mountain meadows.

18. Late Eocene: But 35 million years ago the climate and vegetation were quite different. There were several differences in the regional and continental geography that accounted for those differences. Because of continental drift, Antarctica and South America separated and the circum-Antarctica current developed. This changed worldwide oceanic circulation patterns and resulted in a worldwide cooling trend. Also, the North American Continent has been moving northwestward at the rate of about 1 inch per year. How far has it moved in the past 35 million years? (Colorado was about 600 miles southeast of where it is now).

19. Mountains: Also, at that time there were no major mountain ranges to the west of present day Colorado. Thus, there was nothing to block storms from the Pacific Ocean from carrying moisture to the area. Today, the coastal ranges, the Sierra Nevadas and Cascades, block many of the moisture laden clouds, causing a rain shadow. The moisture falls on the western flanks of those mountains and results in a much wetter climate on the west side than on the east.

20. Monument Valley: Also, there is evidence that plateau uplifts in the western U.S. (the Colorado Plateau) and Asia (the Himalayan Plateau) have resulted in a general global cooling trend in the past 40 million years. Whatever all the factors were we may never know. We do know that the climate of ancient Florissant was warmer and wetter then. We can see this from the fossil record, which includes Sequoia trees and many types of hardwood trees that today grow in wetter, milder climates. Where do redwood

trees grow today? How does geography affect their environment?

21. Petrified Redwood Stump (Florissant): We know about these tremendous changes in the earth, in part, from fossils. While some of the dynamic processes on our earth, like volcanoes, have resulted in helping to preserve these clues to ancient life and climate, there are other natural processes that help to destroy them. 35 million year old petrified redwood trees are broken apart in a very, very small fraction of that time by freeze\thaw cycles in which water filling small cracks in the petrified wood is frozen and expands, pushing the wood apart.

22. Broken up Stump: These stumps withstood the millennia until they were exposed to physical and chemical weathering by people who dug them up to show as a tourist attraction. Now they are deteriorating rapidly.

23. Stump With Pine Tree: Continued weathering breaks down the petrified wood until it turns into soil and supports new life. The plants and trees that take root help to break down the stump even further, with their roots penetrating into the stump and breaking it apart as they grow.

24. Deteriorated Shale: This soil building process is a natural, ongoing factor in the deterioration of fossil resources. The "paper)' shales of Florissant Fossil Beds break down very quickly once the overlying caprock deteriorates or is removed.

25: Landslide: Erosion and landslides expose fossils to the elements.

26: People: While these natural processes are taking their toll, as in the example of Florissant Stumps, there are things that humans do that accelerate these processes that result in the deterioration and loss of fossil resources.

27: Poached Fossil: Digging fossils and taking them out of context without keeping good field records destroys millions of years of fossil information in a few minutes.

28. ORV Tracks: Something as seemingly harmless as offroad driving can result in erosion, causing fossil loss.

29: Crystal Forest: Once this area in Petrified Forest National Park was carpeted with petrified wood. As you can see, it looks very different now. Through the years, people took away what may have seemed to be insignificant amounts of wood. But with time, it all adds up and now little remains.

30. Entry Station: This is where the role of the National Park Service comes into play. The NPS is charged with preserving and protecting many of our national treasures, including some of the world's premier fossil sites. Informing visitors of the park rules and regulations is a first step in protection.

31: Law Enforcement: Through regular patrols, law enforcement rangers are able to prevent theft and vandalism of fossils....

32. Rangers on Horse Patrol: and patrols of backcountry and wilderness areas monitor fossil resources, noting any damage or vandalism.

33. Paleo. Demo: While the NPS is charged with preserving and protecting, it is also

supposed to provide for the visitor enjoyment. This dual mandate can be difficult to fulfill, because at times the two responsibilities can be conflicting.....

34. Daemonilix: especially since fossils are sometimes best preserved if they are underground where no one can see them. Cases like this one, protecting the Daemonilix (Devils Corkscrew) at Agate Fossil Beds National Monument, are one way to protect fossils but still allow visitors to enjoy them.

35. Program: Education is another way to meet this dual mandate effectively. Through interpretive programs, visitors can learn about the chain of events leading to fossil formation,..

36. Ranger with people: the story that the fossils tell about the past, and the ways in which each fossil site is unique. This knowledge helps them to understand why it is so important that fossils be protected, as the information they offer is irreplaceable. Interpretation of the fossils and the clues they hold gives them an understanding and appreciation for the site and the job that the National Park Service is doing.

37. Ongoing research by Park Staff and affiliated universities continues to provide new information about the fossils and geology of the area and ensures that the visitors receive an updated version of the on
going story of the past.

38. This effort of the National Park Service to preserve, protect and interpret our fossil resources means that these valuable insights to the past are appreciated by present and future generations.

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Solutions (mineral): Grow A Crystal
Uniformitarianism: Food Chain Game, Make a Diorama
Volcanoes: When Worlds Collide

National Park Service Fossil Sites

Agate Fossil Beds National Monument P.O. Box 427 Gering, NE 69341 (308) 436-4340	Fossil Butte National Monument P.O. Box 592 Kemmerer, WY 83101 (303) 877-4455
Badlands National Park P.O. Box 6 Interior, SD 57750 (605) 433-5361	Hagerman Fossil Beds National Monument P.O. Box 570 Hagerman, ID 83332 (208) 733-8398
Dinosaur National Monument P.O. Box 210 Dinosaur, CO 81610 (303) 374-3000	John Day Fossil Beds National Monument 420 W. Main St. John Day, OR 97845 (503) 575-0721
Florissant Fossil Beds National Monument P.O. Box 185 Florissant, CO 80816 (719) 748-3253	Petrified National Forest Park Petrified Forest, AZ 86028 (602) 524-6228

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