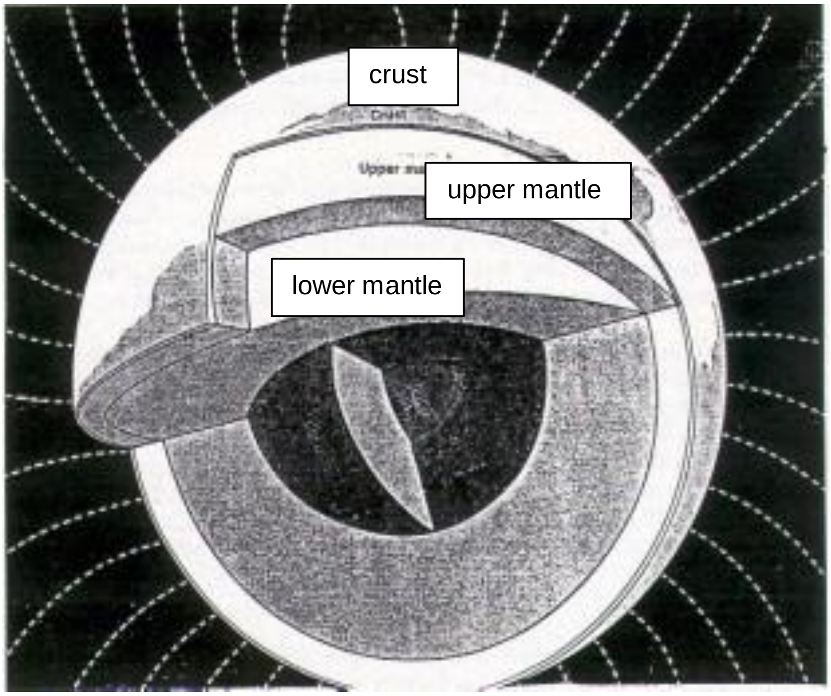
Teacher's Introduction

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.

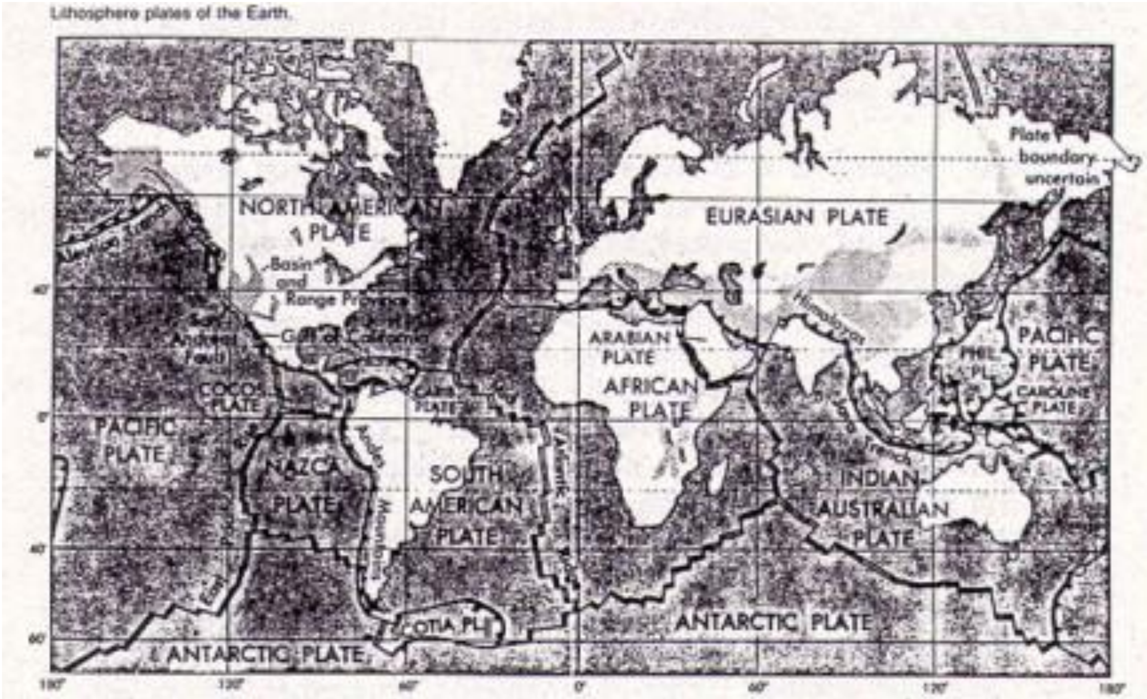
Plate Tectonics: Geophysicists (scientists who study the physics of our changing earth) have developed a theory, plate tectonics, that explain in part the ever changing nature of our home, Earth. Tectonics, from the Greek meaning "builder", is the study of movement and deformation of the earth's crust. 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.



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.

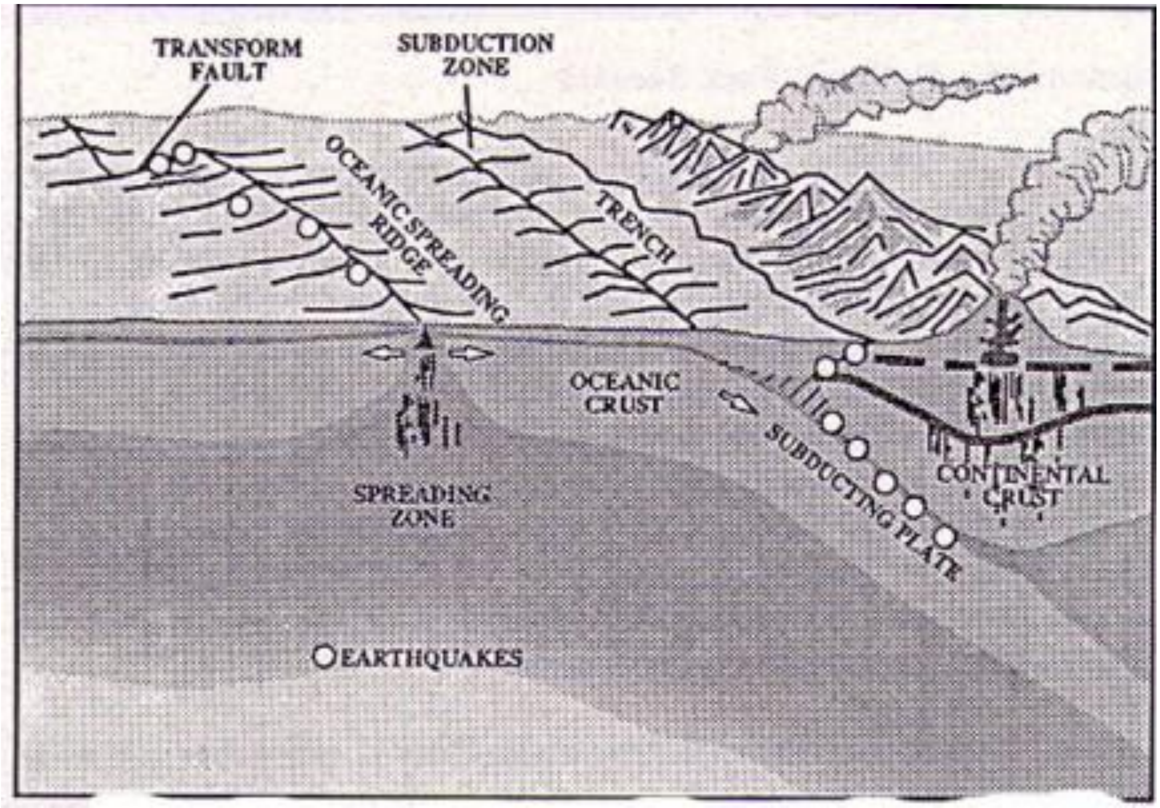


The mid-ocean ridge is a series of huge mountain ranges that extend along the floor of the oceans. It is the largest system of mountains on the planet, with the mountain ranges interconnected like the seams of a baseball. As molten rock escapes from the mid-ocean ridge, it cools and hardens, adding to 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. "Pangaea’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 terrains 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.

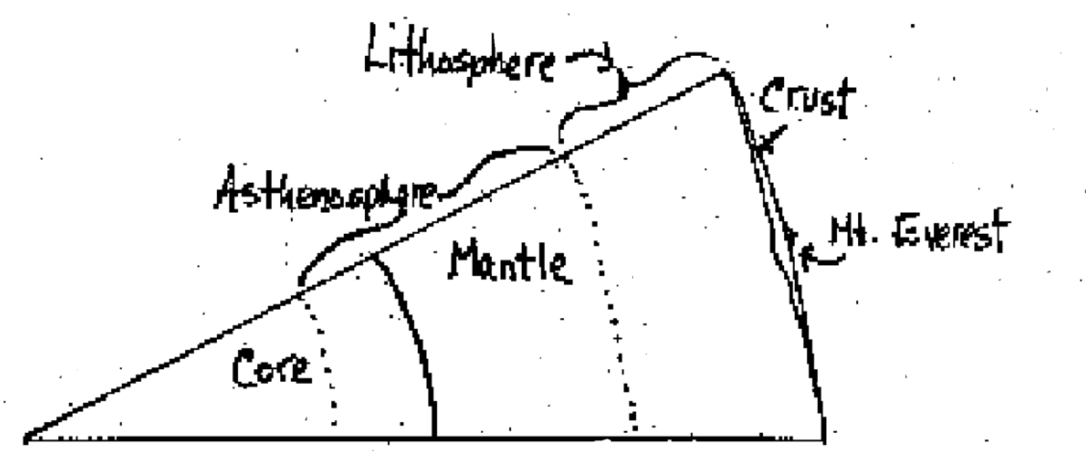
Follow Up: Discuss the possible consequences of the rigid lithosphere resting on the softer, semi-liquid asthenosphere. A pool cover rests on top of a pool and floats. What if, instead of a pool cover all one piece, the top of a pool is covered with several large rafts? These large rafts would correspond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

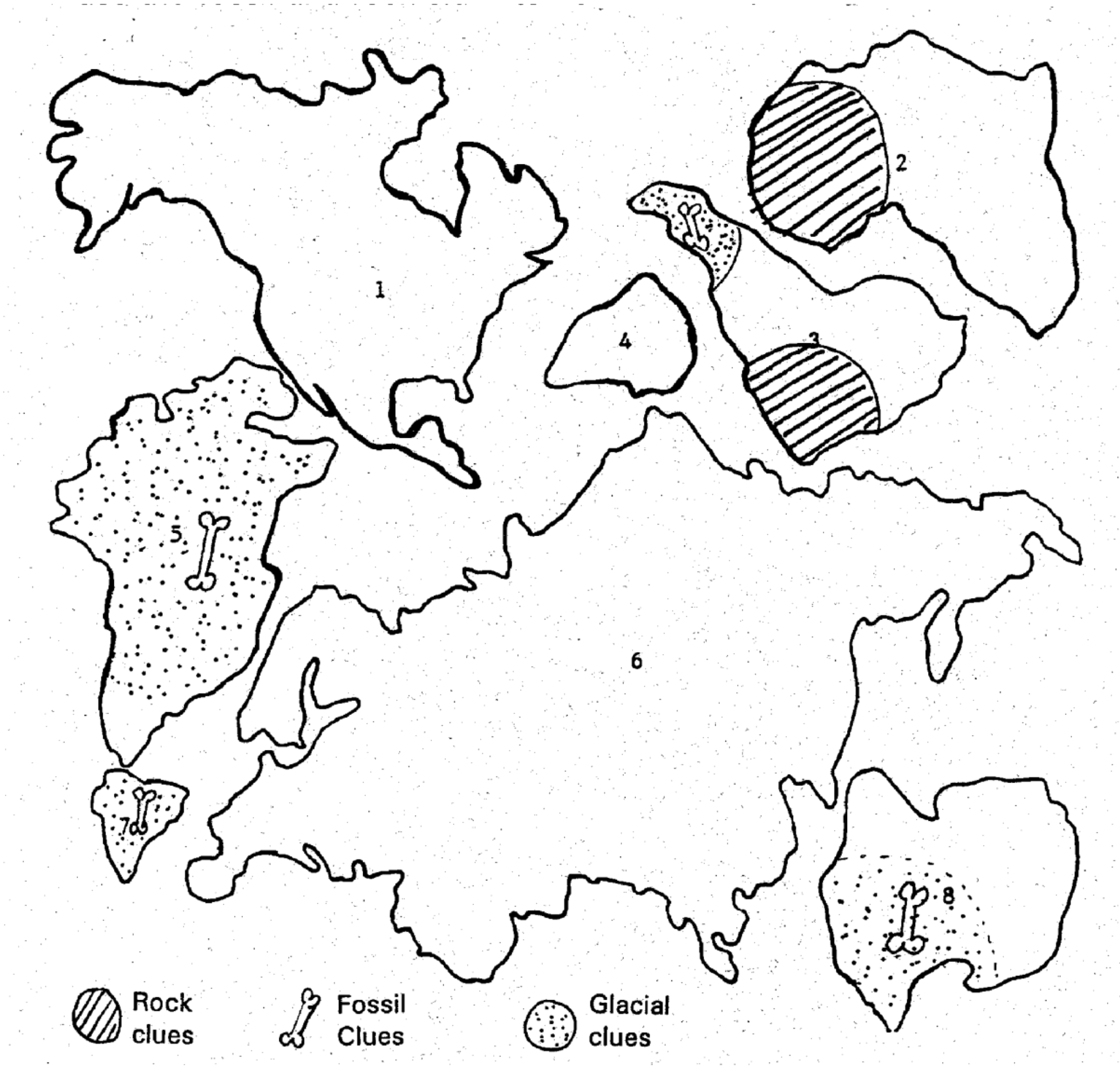
Background: Look at a map of the world. Do you see places where the continental boundaries might fit together like pieces of a puzzle? Back in the early part of the century, during the 1920's, a meteorologist named Alfred Wegener noticed the similarities in shapes and showed how all the continents could 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 Pangaea. 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 Pangaea 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
Pangaea'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.

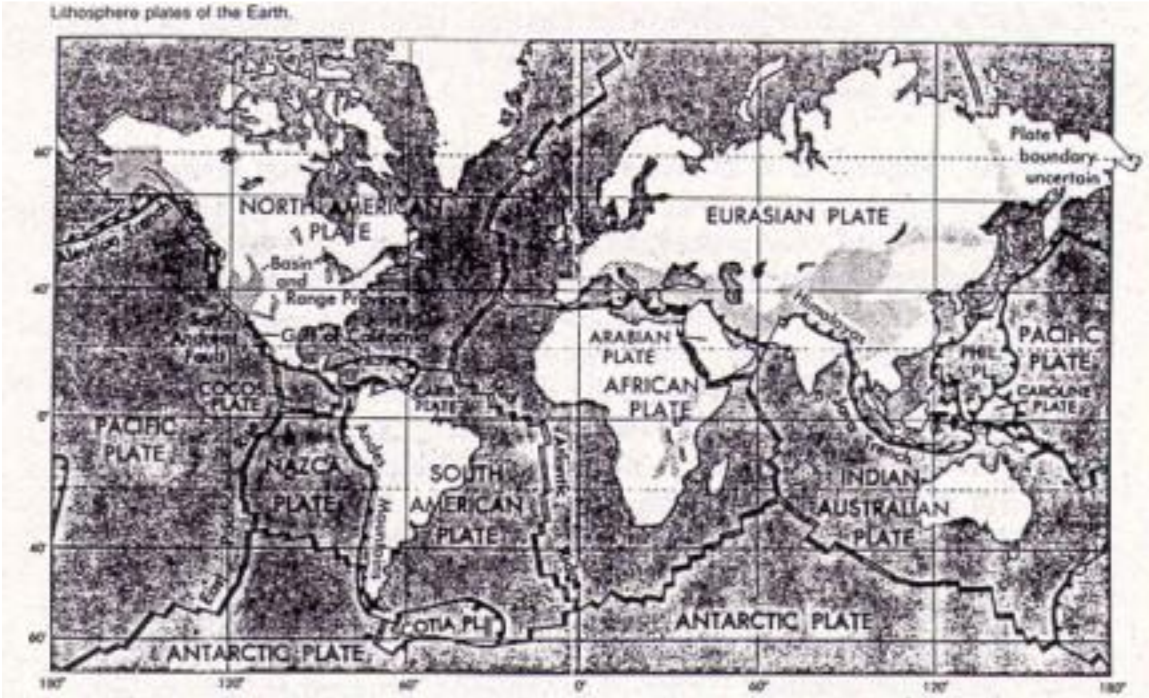
Directions: Pass out copies of the handout "When Worlds Collide" on the next page and a copy of a world map. Have the students, or teams of students, locate the sites of the volcanic eruptions and earthquakes and relate them to plate boundaries.

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 is 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 tartar, salt, oil, water

Procedure: Mix together 2 1/2 cups flour with 1 tablespoon cream of tartar 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 square 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 square 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 connote 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?

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.

Index of Activities by Concept

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