Geology

"Among these mighty cliffs and domes there is no word of chaos, or of desolation; every rock is as elaborately and thoughfully carved and finished as a crystal or shell."
—John Muir

Introduction

Geology is not simply a science of rocks. It is a broad, integrated science which includes the study of plate tectonics, volcanoes, landslides, earthquakes, erosion, rocks, minerals and fossils. The study of geology can be awe-inspiring. Sir Francis Galton said, "When I contemplate the aeons of Geologic Time thru which Evolution has proceeded, I feel my life is as a tiny wave lifted up for a moment on an Inland sea."

Spend time examining rocks in your park and discuss the geomorphology (the study of landforms and the processes by which they were created) that make your park unique. In a historic park, you could visit a stone building. Where did the rocks come from? Who brought them to the site? One example: The summit building at Mount Diablo State Park contains ancient marine fossils embedded in its sandstone walls.

From the outset, it is important to distinguish between landforms and the rocks from which they're made. They can, and often do, have different origins and ages. A mountain uplifted by local faulting may contain rock material formed millions of years earlier in an ocean basin hundreds of miles away. Whenever discussing geology with park visitors, the interpreter must keep this distinction in mind; otherwise, confusion will result.

When interpreting geology, you may want to give the Junior Rangers a sense of the scope of the science, but don't forget to be specific, as well. Alternatively, you may choose to focus (in depth) on one area of this vast science.

At an introductory level, geology allows the visitor to exercise his or her powers of logic and deduction. Rocks often provide common-sense clues to the ancient environments that once existed in an area. Rub your hand over a piece of sandstone, loosening the grit. Children can easily equate the sand with beach or dune settings they've visited in the past. Similarly, a piece of conglomerate may denote a long-vanished stream bed; "limy" rock, a shallow sea; and lava, volcanic vents not too far away. If you learn the relative ages of the rocks in your area (consult geologic maps for this), then a rough outline of your park's geologic history can often be pieced together . . . using the deductive skills of both interpreter and audience.

Interesting Geology Facts

- Tsunamis can barrel through the ocean at 600 miles per hour. That's as fast as the cruising speed of a jet plane.

- California is moving because of plate tectonics. In 100 million years, part of California will be up near Alaska. Brrrr!

- All of the continents on the planet (Europe, Asia, Australia, Africa, South America, North America, Antarctica) were once (about 250 million years ago) combined into a super-continent scientists have named Pangaea.

- When Mount St. Helens erupted on May 18, 1980, it sent a cloud of ash 12 miles into the air, some of which was deposited hundreds of miles to the east by prevailing westerly winds.

- Mauna Kea, a Hawaiian volcano, is the tallest volcano in the world. When measured from its base on the ocean floor to its summit, it is over 33,000 feet high—more than 4,400 feet higher than Mt. Everest!

- In the winter of 1811 to 1812, a series of earthquakes in New Madrid, Missouri set off geysers, caused islands to disappear from the Mississippi River, and rattled windows in Washington, D.C.

Sample Program: Geology

I. Introduction
   Introduce yourself to the group.
   Introduce the Junior Ranger Program.

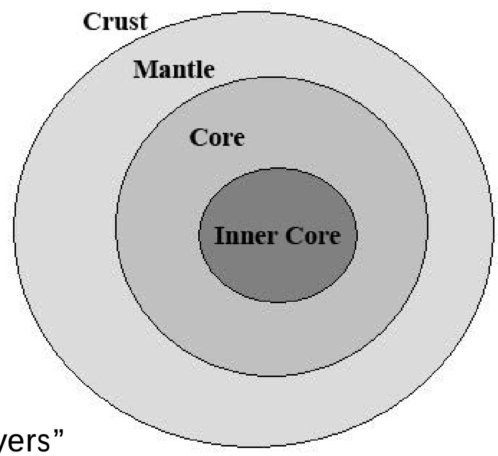
II. Focus

Ask the Junior Rangers what they think geology is (they will probably say "the study of rocks"). Tell them that geology is much more than just the study of rocks.

III. Objectives
Today we are going to find out about the rocks in the park. How were they formed? How did they get there? How was the earth formed?

IV. Inquiry/Discussion

A. Formation of the earth
1. How long ago do you think the earth was formed?
   4.5 billion years ago
2. Is the earth solid?
   No—The earth is made up of many layers. At the center there is a hard iron core. On top of that, there is a layer that is so hot it oozes very slowly. And our continents are on plates that move. The sea floor moves too.



3. Describe the characteristics of the different "layers" of the earth.
4. Activity: The Earth, Inside and Out (see activity section below)

B. Earthquakes
1. Have any of you ever experienced an earthquake?
2. How long do they usually last?
   A few seconds to a minute
3. Can earthquakes happen anywhere?
   Yes
4. Are they more likely to happen in one place than another?
   Yes, they are more likely to occur on or near plate boundaries.
5. Can you name an earthquake fault line in California?
   The San Andreas Fault, the Hayward Fault, etc.
6. How do scientists measure how big an earthquake is?
   They use the Richter Scale. With every point on the Richter scale the degree of ground shaking changes by a factor of ten (the amount of energy released changes by a factor of 32). For example, an earthquake that measures 5 points on the Richter Scale results in ten times the level of ground shaking than an magnitude 4 earthquake.

C. Volcanoes
1. What is a volcano?
   A volcano is one or more openings, or vents, in the surface of the earth through which molten rock, gases, solid material (such as ash and solid rock) and steam are forced out. Volcanoes often form near plate boundaries. Where plates are moving apart, lava may ooze out of vents on the ocean floor.
2. How do volcanoes erupt?

The way a volcano erupts depends on the characteristics of the magma (hot, molten rock from deep in the earth), the shape and length of the vents, and whether or not the vents are plugged by rock. For example, some eruptions are very quiet and the lava that flows out is very runny. Other eruptions are violent, flinging out 20-mile (32 km) columns of ash or forming ash clouds that are loaded with bits of lava. The type of eruptions a volcano produces influences the way it looks. For example, if a volcano usually ejects runny lava, a gently sloping, dome-shaped mountain will form.

3. Activity: Make a volcano (see activity section below)
4. Do volcanoes do anything good?

   Although the eruption of a volcano can be one of the most destructive forces on Earth, volcanoes also build new land, produce mineral-rich ash that helps fertilize the soil, and produce gases that are important to life on earth.
5. Volcanoes don't always extrude ash. What else comes from volcanoes?
6. Name a rock that comes from a volcano.

   Obsidian, pumice, others
7. The kind of rock that comes from a volcano is called igneous. Show a sample of a glass-like igneous rock (obsidian, for example). What do you notice about this rock?

   It's shiny and smooth in places, like glass.

   Some kinds of igneous rocks look glassy because when they came out of a volcano they were very hot and cooled very quickly on the earth's surface. Not all igneous rocks look like this. Basalt, for example, is an igneous rock that is not shiny. Other kinds of igneous rocks cool very slowly under the earth's surface. These rocks have well-formed crystals. Sometimes, changes in temperature and pressure within the earth's crust change a rock into another kind of rock. These new rocks are called metamorphic rocks.
8. Show examples of original and metamorphic rocks (limestone/marble or shale/slate, for example).
9. To represent how a rock changes into a metamorphic rock, take a piece of bread and squeeze it into a ball. Explain that if you then heated (or toasted) this bread ball, it would be like a metamorphic rock: still made up of the same "ingredients," but now in a different form and with different characteristics.
10. Still other kinds of rocks are formed on river, ocean, and lake bottoms from layers of sand and mud. Over time, pressure or evaporation cements these layers into rocks. These are called sedimentary rocks. Sometimes shells and animal bones can become part of sedimentary rocks. Show an example of a sedimentary rock—one that shows the layers of material, such as sandstone, shale, or limestone.
11. What type of rock would have fossils in it?

    Sedimentary

12. Take time to investigate your own park's geologic environment. Show examples of local rocks. Are they igneous? Sedimentary? How can you tell? Smell! Touch! Taste! Examine in detail. Have the children imagine how the rock may have gotten there. Was it brought down by a river? Extruded from a volcano? Look for signs of nature's impact on landforms. Are there land or mud slides? Wind, water, or ice erosion? What evidence of erosion can you find? Discuss how wind, water, and ice can be “stronger” than solid landforms by eroding them over time.
13. Your park will have its own individual character. Discuss relevant geology: mountain formation, stream erosion, sand dune formation, beach migration, etc.
    a. Why are pebbles round and smooth?
       From the action of water
    b. If a rock is rough with sharp edges, what does this tell us?
       It could have been broken by plant roots or it fell and was broken by a hard landing, or possibly it was eroded by ice.
    c. What is soil?
       Broken down rock, dead plant and animal material, and flood deposits that plants have started to grow on.
    d. Is soil the same down to the rock?
       No—only the uppermost layer has nutrients from decayed plants and animals. It is the only layer that can be used by farmers.
14. Encourage the children to investigate their own yard. What types of rock might they find?

V. Application/Conclusion
   A. Ask Junior Rangers to tell you what they have learned.
   B. How can we be safe in an earthquake?
      1. Get under a sturdy table or desk, or stand in a doorway.
      2. Stay away from windows and objects that may fall.
   C. Announce the next Junior Ranger program and other interpretive programs.
   D. Stamp logbooks.

Activities

Make a Volcano

Equipment needed: dirt or damp sand, small jar with wide neck, quart size container, ¼ cup white vinegar, ¼ cup dishwashing liquid, ½ cup water, 4 tablespoons baking soda, red food color

Make a mountain of dirt or sand about a foot high. Bury the small jar in the top of your mountain with the opening sticking out. Put the baking soda in the small jar. In the large container, mix the water, soap, vinegar, and a few drops of red food coloring to make the mixture look like hot lava. Pour some of the mixture into the small jar to create an eruption. You may have to stir it slightly. When baking soda and vinegar are mixed together they form carbon dioxide, a bubbly gas. These bubbles mix with the soap and come pouring out of the top of the volcano like lava.

Picture It

Unless you've seen a volcanic eruption or experienced an intense earthquake, it's hard to comprehend the incredible forces that exist within the earth. Try showing pictures of volcanoes, faults, earthquake damage/effects, tsunamis, and geysers.

Rockin' and Rollin' Ground

Have the kids form two lines facing each other. Tell them that they represent the two plates on either side of the San Andreas Fault in California. Have one child join hands with the person opposite him or her and explain that they represent a fence that stretches across the fault. On your signal, have the two lines take ten sideways steps in opposite directions. The “fence” should stretch and finally break during the shift.

Racing an Avalanche

Have the kids line up, then place a marker 100 feet away. Explain that they'll be trying to run faster than the hot mud and ash that flowed down Mount St. Helens' slopes after its 1980 eruption. Give the signal and time the kids as they run to the marker. When they catch their breath, tell them that they were all beaten by the avalanche. It sped down the mountain at about 100 miles per hour and would have finished the race in less than one second! (Point out that not all lava, mud, and other material ejected from volcanoes flows this fast.)

Timed Quakes

Divide the kids into pairs and have one person in each pair keep time while the other one shakes. Tell the “shakers” they should shake until one minute is up. Were they right? Then have the kids switch roles. Afterward tell the kids that most earthquakes last for less than one minute, but a severe earthquake in Alaska in 1964 shook the ground for several minutes.

Rock Hunt

Take the group on a rock hunt so the kids can search for their own special rock samples. Have them try to find four or five interesting and different-looking rocks to study. Study each of the rocks carefully. (You can pass out hand lenses to let them get a closer look). Explain that they should think about how each rock feels and looks.

Have each Junior Ranger pick out a favorite rock and put the others aside for the time being. Have them think up words that describe their rocks. Now have the children get into small groups and put all their collected rocks into a pile. Tell each group to separate their rocks into two piles according to any of the characteristics they just came up with. For example, the kids could sort their combined collections into piles of rocks that are dark or light, smooth or rough, shiny or dull, and so on. Let them come up with some other ways to sort the rocks, such as by color, size, or shape. Point out that scientists also make categories for rocks based on the rocks' similar features. (After the activity, ask the Junior Rangers to put the rocks back where they found them).

Metamorphic Bread

During a discussion on types of rocks, use a slice of bread to take the place of a "normal" rock. Then show how metamorphic rocks are changed by pressing and shaping the bread slice until it is a ball of dough. This activity demonstrates that although the bread ball is made up of the same ingredients as the original slice, its shape, consistency and features have been changed. (If you then "toasted" or baked the bread, it would be even more like a metamorphic rock!)

Stone Identification

Ask each Junior Ranger to find a stone. With the group sitting cross-legged in a circle, ask everyone to feel their stones carefully without looking at them. Give them a minute or so to do this, then ask everyone to pass their stones to you. After jumbling them up, cover each stone with your hand and pass it to your right. Tell everyone to try to identify the stone they chose by its feel. Each time a person receives a stone, she will feel it to see if it is hers. When she thinks she has found her stone, she is to let it drop to the ground and continue passing any other stones that are passed to her. Do not tell them in advance why they are to feel the stone, and emphasize the importance of not looking at it. When all stones have been claimed, have each person check to see if he/she was right! (Afterwards, ask the Junior Rangers to put the stones back where they found them.)

From The Interpreter's Guide by William J. Krumbein and Linda Levya. Sacramento: Department of Parks and Recreation, 1977.

The Earth, Inside and Out

Number of children: 12 or more
Environment: Open space
Equipment Needed: None
Purpose of Activity: To learn about the structure of the earth by acting out the characteristics of its different layers
Activity:

1. Explain that the group is going to work together to build the earth. First give each Junior Ranger a part to play. Then, explain what each part does. (See Background Information on page 7-8.) Let the kids practice any sounds or movements and then build the earth from the inside out.
2. Have the child playing the part of the inner core flex his or her muscles or pretend to lift weights and stand in the center of the area. Tell the kids that this represents that the inner core is very dense and is solid metal.

3. Next have the outer core form a circle around the inner core. They should face in, toward the inner core. Then have them walk counterclockwise around the inner core while holding their arms out to the sides and waving them up and down. Tell the kids this represents the fact that the outer core is liquid and is moving.
4. Have the children playing the deep mantle join hands to form a circle around the inner core. (Have them chant "hot rock, hot rock, hot rock.").
5. Have the asthenosphere kids surround the deep mantle. (Have them slowly sway their bodies back and forth to represent the movement that occurs in this layer).
6. Finally, have the lithosphere kids form a circle around the entire rest of the earth. Have them face outward and slowly walk around the rest of the earth. (Have them chant "Moving plates, moving plates.")

Background Information: Geology

Composition of the Earth[1]

The earth is divided into three main layers: a thin outer crust, a thicker mantle, and a core. The outer crust is a thin rocky skin that covers the planet. In comparison to the rest of the earth, it is like a stamp on a billiard ball. At its thickest, it is only 22 miles deep. There are two kinds of crust: continental and oceanic. Continental crust consists of relatively light (and often light colored) rocks made of elements like aluminum, silicon, and oxygen. Although the continental crust is thicker than oceanic crust, oceanic crust is made of denser, heavier rocks (like basalt) containing iron, magnesium, silicon, and oxygen. The heavier oceanic crust underlies the lighter continental crust.

The layer underneath the crust is the mantle, which is made up of much denser material than the crust. The mantle is made up of solid rock in several zones. The mantel and crust, which compose the "lithosphere," are cooler and more rigid than the lower parts ("the asthenosphere"). The asthenosphere is a hot, unstable zone which is solid, but can flow at very slow rate. Geologists think the lithosphere floats on this more mobile zone and slowly slides around on it.

Underneath the lithosphere and the asthenosphere lies the core, at the center of the earth. The core is a mass of hot, heavy metals like iron and nickel, and is a source of heat deep within the earth.

Plate Tectonics

In the 1960s geologists developed the plate tectonics theory. According to this theory, the lithosphere is not a continuous sheet of solid rock, but is divided into

[1] Geology information and activities are from Ranger Rick's *NatureScope*. "Geology: The Active Earth." National Wildlife Federation, 1987.

several huge plates and many smaller plates that float on the top of the asthenosphere. (A plate can be hundreds or thousands of miles across).

Plate tectonics explains how major geological events occur. Most mountain building, earthquakes, and volcanic activity take place along the margins of the plates. The plates interact with each other to affect the crust.

Where two plates pull apart from each other, new oceanic crust is formed. Magma (hot, molten rock from deep in the earth) oozes out of cracks along rifts and hardens to form new crust.

When two plates carrying continents run into each other, the collision crumples both plates and, over millions of years creates mountain ranges. If two plates collide and one is made up of continental crust and the other is made of oceanic crust, the denser oceanic plate gets pushed under the edge of the continental plate. As the lower plate is pushed under, it begins to heat up in the hotter mantle. The ocean sediment on the plate begins to melt, and this melted rock (magma) begins to move upward, often fueling volcanoes in the mountain ranges that have formed on the upper plate.

When two plates slide sideways past each other, the slipping motion often causes earthquakes. In some places, a narrow plume of hot material rises up through the mantle and creates a hot spot under the plate. As the plate slowly moves over the hot spot, a line of volcanoes is formed. As a volcano is carried past the hot spot, it becomes inactive, but in time a new volcano will be formed over the hot spot.

Most of these changes are so slow they go unnoticed, but earthquakes and volcanic eruptions are sudden, dramatic results of plate movement. Land along the San Andreas Fault, the boundary between the Pacific and North America plates, is moving an average of two inches per year. This is about the same rate that fingernails grow.

Volcanoes

Volcanoes usually form along plate boundaries. Where plates are moving apart, lava may ooze out of undersea vents. A volcano is one or more openings, or vents, in the surface of the earth through which molten rock, gases, solid material (such as ash and solid rock), and steam are forced out. The way a volcano erupts depends on the characteristics of the magma, the shape and length of the vents, and whether or not the vents are plugged by solid rock. For example, some eruptions are very quiet and the lava that flows out is very runny. Other eruptions are violent, flinging out 20-mile (32 km) columns of ash or forming ash clouds that are loaded with bits of lava.

The type of eruptions a volcano has influences the way it looks. For example, if a volcano usually ejects runny lava, a gently sloping, dome-shaped mountain will form. Although the eruption of a volcano can be one of the most destructive forces on Earth, volcanoes also build new land, produce mineral-rich ash that helps fertilize the soil, and produce gases that are important to life on earth.

Earthquakes

Earthquakes can happen anywhere that movement occurs along a fault. But most earthquakes occur near plate boundaries. To compare earthquakes, scientists measure each quake's intensity and magnitude. The intensity of an earthquake is a measure of how badly it shakes people and people-made objects. It is measured on the Mercalli Intensity Scale from 1 (only detectable by sensitive instruments) to 12 (causing complete destruction of buildings and other objects).

The magnitude of an earthquake is a measure of how much energy it gives off and is independent of how much damage it causes. Magnitude is recorded by seismographs and is measured on the Richter Scale from about -3 (barely detectable by seismographs) to about 9 (earthquakes that can cause severe damage). Each point on the Richter scale means an earthquake's strength changes by a factor of ten (an earthquake registering 6 points on the Richter scale is ten times bigger than an earthquake measuring 5 points on the Richter scale).

Though a big earthquake can cause a lot of damage, sometimes a greater amount of damage is caused by the fires that rage afterward. As the earth shakes, it often disrupts electrical and gas lines that can, in turn, start fires. And broken water lines make fighting the fires almost impossible.

Geysers

It takes three things to form a geyser: water, a series of irregularly shaped “tubes,” and a heat source hot enough to boil water. The water that is shot out of geysers is usually groundwater, which originates from rain or snow melt that has trickled deep into the ground through cracks and pores in the rocks. As this water circulates deep underground it is heated by hot rocks that in turn have been heated by an underlying body of magma.

How often a geyser “blows” and how long its eruption lasts can vary from geyser to geyser. Some geysers erupt every hour or so, while others may have several hours, days, or weeks between eruptions. And while some geysers may gush for only a few minutes, others may have eruptions that last 45 minutes or more.

Almost all of the world's geysers are in New Zealand, Iceland, and Yellowstone National Park in Wyoming. Yellowstone has approximately 200 geysers—more than the rest of the world combined.

Tsunamis

A tsunami is a giant ocean wave that starts when a sudden motion in the earth jolts and displaces the water in the ocean. Undersea earthquakes, coastal earthquakes, and volcanic activity are the usual causes of tsunamis. Most tsunamis occur in the Pacific Ocean.

The height and speed of a tsunami are affected by the depth of water it is traveling through. Out in the middle of the ocean, a tsunami may be only three feet high, but when it reaches the shore it may tower above land 100 feet or more. The wave is so large that a boat at sea may rise and fall without being aware that a huge wave is passing under it. A tsunami can travel through the ocean at 600 miles per hour.

Fossil Formation

Fossilization occurs when organisms, either plant or animal, or evidence of activities, such as droppings, pollen grains, footprints, etc., are covered in sediment of some kind before scavenging animals or the natural processes of erosion or decay completely destroy them. Rapid burial of this kind is most likely to occur in the sea where a continuous rain of debris (like silt and fine sand) falls onto the sea floor. As a result, scientists have found many more fossils of sea creatures than land creatures. Land dwelling animals are generally preserved as fossils when their bodies are washed into lakes or into the sea, although some have been preserved in sand dunes. Usually only the hard parts like teeth, shells, and bones get preserved, since soft tissues—skin, muscles and sinews, for example—tend to decompose quickly. However, soft-bodied jellyfish and worms have been fossilized. A fossilized bone isn't exactly the same bone because even parts of bone can decompose. New minerals from the water or soil around the bone enter the pores (spaces) left by the decomposed material, making the bones strong and hard again, and heavier.

Rock Formation

<u>Igneous Rocks</u>

Igneous rocks are formed when molten rock material called magma cools and hardens.

- Volcanic Igneous Rocks: These rocks are called extrusive igneous rocks. Some of these extrusive rocks (such as obsidian) appear glasslike because they cool rapidly on the earth's surface (However, not all appear glassy: basalt is an extremely common non-glassy extrusive rock). These rocks are very fine grained and have small, poorly formed crystals.

- Plutonic Igneous Rocks: These rocks are called intrusive igneous rocks because they cool very slowly beneath the surface of the earth. Intrusive rocks form when magma is pushed up toward the crust, but cools and crystallizes before it reaches the surface. Because of this slow cooling, intrusive rocks have large, well-formed crystals.

<u>Sedimentary Rocks</u>

Sedimentary rocks originate from fragments of other rocks, from minerals that are deposited chemically, or from accumulation of organic material. These rocks accumulate on the surface of the planet, often underwater. Sedimentary rocks cover 75 percent of exposed land mass, but compose only 5 percent of the crust. Sedimentary rocks are often layered rocks. Most get their start when wind, ice and water wear down rocks into bits of sand, soil, mud, pebbles, clay and other loose sediment. As this sediment washes into rivers, lakes and oceans, it piles up, layer upon layer. Over time, as the pressure on the bottom layers increases, the sediment compacts and cements together to form solid rock. For example, sandstone is a sedimentary rock that is made up of layers of compressed and cemented sand grains (usually quartz). And shale is a sedimentary rock made up of layers of mud (very fine-grained quartz, feldspar, and clay minerals).

Sometimes sedimentary rocks and minerals are formed by the evaporation of water that contains various dissolved substances. When the water evaporates, the minerals crystallize. Two examples of sedimentary rocks that form in this way are halite (formed from dissolved sodium chloride) and some types of limestone (formed from dissolved calcium carbonate).

Coal, chalk, and a few other sedimentary rocks form from organic material, such as the shells or skeletons of plants and animals. For example, shellfish can use calcite dissolved in the water around them to build their shells. When these animals die, their shells pile up on the bottom. As the shells become cemented together, limestone often forms.

The four processes involved in the creation of sedimentary rocks are:

1. Disintegration: The chemical and mechanical breakdown of rock on the earth's surface. (e.g. by wind, ice)
2. Transportation: The movement of these particles to an endpoint (e.g. by river).
3. Deposition: The act of dropping these particles at their endpoint.
4. Compaction/Cementation: The conversion of the particles into solid rock layers.

<u>Metamorphic Rocks</u>

Metamorphic rocks undergo changes deep within the planet's interior. They generally occur because of temperature, pressure, or chemical differences that result in the melting and re-crystallization of the rock.

When igneous and sedimentary rocks are subjected to intense heat and pressure deep within the earth, their mineral composition and grain size can change, and they become metamorphic rocks. For example, metamorphism can recrystallize the calcite grains in limestone, forming marble. And shale, when subjected to intense heat and pressure, changes into the metamorphic rock called slate. You can often see new minerals in metamorphic rock, such as garnets, as well as once-flat sedimentary layers that have been bent and twisted from the heat and pressure.

Metamorphic rocks yield compelling clues about past dynamic interactions of the tectonic plates of the earth's crust. Metamorphic "belts" are commonly associated with mountain ranges. In addition, metamorphic rocks can provide a window to the past, even when all topographic and surface evidence has faded.

Suggested Resources: Geology

Alt, David D. and Donald W. Hyndman. *Roadside Geology of Northern and Central California*. Missoula, MT: Mountain Press Publishing, 2000. A very useful and readable geologic guide to regions and roadsides in the northern and central part of the state.

Bachert, Russell E., Jr. *Outdoor Education Equipment*. Danville, IL: Interstate Printers and Publishers, 1974. This is a valuable collection of instructional aids that can be easily and inexpensively assembled for use in field investigations.

Bates, Robert L., and Julia A. Jackson, Eds. *Dictionary of Geological Terms*. Third ed. New York: Anchor books, Doubleday, 1984. Geological dictionary that defines terms used in the field of geology.

California Division of Mines and Geology. *California Geology*. This very useful publication is no longer in print, but is still available in some libraries.

Collier, Michael. *A Land in Motion: California's San Andreas Fault*. San Francisco: Golden Gate National Parks Association, 1999. Written in a journalistic style, this source offers lay readers an up-to-date introductory overview of "the most famous fault on earth."

Harden, Deborah. *California Geology*. Upper Saddle River, NJ: Prentice Hall, Inc., 1998. An interesting overview of California geology.

Hill, Mary. *California Landscape: Origin and Evolution*. Berkeley: University of California Press, 1984. A well-written guide to earth processes which have created today's landforms.

Hill, Mary. *Geology of the Sierra Nevada*. Berkeley: University of California Press, 1977. A good reference on the development and geologic history of the Sierra Nevada mountains.

Iacopi, Robert. *Earthquake Country*. Fourth Ed. Tucson, AZ: Fisher Books, 1996. This work contains updated discussions of plate tectonics, earthquake mechanics and measurement, historic shocks, future seismic prospects, and preparedness tips.

Jaeger, Edmund C. *The California Deserts*. Fourth Ed. Stanford, CA: Stanford University Press, 1965. Written by an authority on the subject, this source gives a very nice overview of Southern California desert natural history.

Kious, W. Jacquelyne and Robert I. Tilling. *This Dynamic Earth: the Story of Plate Tectonics*. U.S. Department of the Interior, U.S. Geological Survey, 1997. An excellent primer on plate tectonics.

Logan, William Bryant. *Dirt: the Ecstatic Skin of the Earth*. New York: Riverhead Books, 1995. A collection of short essays contemplating soil.

Norris, Robert M. and Robert W. Webb. *Geology of California*. Second edition. New York: John Wiley & Sons, 1990.

Oakeshott, Gordon B. *California's Changing Landscapes: A Guide to the Geology of the State*. New York: McGraw-Hill Book Co., 1978. A good overview of the state's geologic history, features, and processes, updated to include plate tectonics.

Pellant, Chris. *Rocks and Minerals*. New York: Dorling Kindersley, Inc., 1992. A good key to rock classification.

Quinn, Kaye. *Planet Earth*. Los Angeles: Enrich, 1986. Contains games, activities and puzzles about earth science.

Ranger Rick's *NatureScope*. "Geology: The Active Earth." National Wildlife Federation, 1987.

Raymo, Chet. *The Crust of Our Earth: an Armchair Traveler's Guide to the New Geology*. Englewood Cliffs, NJ: Phalarope Books, Prentice-Hall, Inc., 1983. Modern geology presented by a master storyteller.

Sharp, Robert P. *Geology: Field Guide to Southern California*. Dubuque, IA: W.C. Brown Co., 1976. Contains detailed road guides to the geologic provinces of Southern California.

Sharp, Robert P., and Allen F. Glazner. *Geology Underfoot in Southern California*. Missoula, MT: Mountain Press Publishing Company, 1993. The authors present twenty "vignettes"—each a story focused on some geological subject of particular interest and significance. Several involve California state park units.

Shelton, John S. *Geology Illustrated*. San Francisco, CA: W.H. Freeman, 1966. Well-illustrated with aerial photos; emphasizes Western U.S. geology, with many topics specific to California.

Sussman, Art. *Dr. Art's Guide to Planet Earth: for Earthlings ages 12 to 120.* White River Junction, VT: Chelsea Green Publishing Company, 2000. This book explores how our planet works and how our actions can affect the environment.

Watts, May T. *Reading the Landscape of America*. New York: Macmillan Publishing Co., Inc., 1975. These essays about selected American habitats are well-crafted pieces of interpretation, blending personal experience with natural (and human) history.

Other Sources of Information

American Geological Institute has books and pamphlets on many geology topics, including *The Making of a Continent*, a companion volume to the PBS series of the same title. *Earth Science*, a quarterly geology magazine for the general public and "A Study in Time," a poster on geologic time periods, are also available. For more information write American Geological Institute, 4220 King St., Alexandria, VA 22302. www.agiweb.org/geoeducation.html.

Department of Conservation. "California Geological Survey." A good resource for California-related geologic information. It contains publications and links to other organizations. www.consrv.ca.gov/CGS/index.htm.

Department of Conservation. Division of Oil, Gas and Geothermal Resources. "Kids & Educators." This webpage contains good illustrative drawings of oil machinery and easy to understand information on natural energy resources. www.consrv.ca.gov/dog/kids_teachers/index.htm.

Earthquake Information Bulletin is available by single copy or by subscription from the U.S. Government Printing Office. Other geology publications are also available. Write U.S. Government Printing Office, Superintendent of Documents, Washington, DC 20402-9325.

Massachusetts Audubon Society has reprints from the *Curious Naturalist* on geology topics including "Snow Geology," "Pangaea—Drifting Continents," and "Energy From the Earth." "The Rock Cycle" and "Geologic Time" are charts that are also available. www.massaudubon.org.

Rocks is an activity guide available from British Columbia Teachers Federation. For a catalog, write to B.C. Teachers' Federation, Lesson Aids Service, 2235 Burrard St., Vancouver, BC V6H 3H9. www.bctf.bc.ca.

U.S. Geological Survey has many pamphlets, books, maps, lists of resources, and a "Selected Pack of Geologic Teaching Aids" among other items. Many of these materials are free. For more information, write U.S. Geological Survey, Geologic Inquiries Group, 907 National Center, Reston, VA 22092. earthquake.usgs.gov/learning/kids.php.

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