10. Earth Processes

While the ground beneath our feet may seem stable, our Earth is actually an amazingly dynamic and fluid planet. Huge sections of crust called “plates” are always on the move, spreading apart from each other at some places like under the Atlantic Ocean, sliding past each other at other places like the San Andreas Fault, crashing together at still other places to lift mountains like the Himalayas. Here you will learn about such processes, the definition of a rock, and how rocks of different sorts are formed by earth processes.

Activity 10.1: What is a rock?
Learn the definition of a rock and the three rock types (igneous, sedimentary, and metamorphic). Collect at least one of each of the three rock types.

Activity 10.2: Plate tectonics and the rock cycle.
Our earth is made of huge segments, or plates, that are constantly on the move. They recycle rocks and create processes and conditions that lead to igneous, sedimentary, and metamorphic rocks. Make a poster showing the rock cycle. Include specific examples of the different sorts of rocks you might find along different parts of the rock cycle.

Activity 10.3: Igneous rocks.
Learn about different sorts of igneous rocks, how they formed, and how they differ from one another, such as granite versus basalt versus obsidian versus pumice. Then do one of the following activities: a) use a sugar candy recipe to demonstrate the effects of quick versus slow cooling and gas bubbles in forming the texture of an igneous rock; b) make a plaster or clay volcano and set it off for your fellow club members; or c) make an igneous rock collection of 3 or more different types.

Activity 10.4: Sedimentary rocks.
Learn about wind and water erosion and deposition and chemical precipitates and evaporates in order to understand how sedimentary rocks form. Then do one of the following activities: a) make a precipitate or sandstone, conglomerate, and breccia and create a geologic column of these in a milk carton or observe sedimentary processes in nature or in the lab; b) make fossils with clay and plaster; or c) make a sedimentary rock collection of 3 or more different types.

Activity 10.5: Metamorphic rocks.
Learn about “parent rocks” and the formation of metamorphic rocks due to heat and pressure. Then do one of the following activities: a) using clays of different colors as your “parent rocks,” make a metamorphic rock with pressure and heat by twisting and rolling the clays together and then baking them in an oven; or b) make a metamorphic rock collection with 3 or more different types.

Activity 10.6: Making 3D models of geologic features related to plate tectonics.
Understanding some earth processes can be hard without visualizing them. Craft 3D paper models to illustrate geologic features related to plate tectonics.

Activity 10.7: Earthquakes.

Somewhere in the world, an earthquake is happening even as you read this sentence. Explore how and why by researching major earthquakes throughout history, exploring the underlying causes of earthquakes, or modeling their effects.

10. Earth Processes

□ 10.1 What is a rock?

□ 10.2 Plate tectonics and the rock cycle

□ 10.3 Igneous rocks

□ 10.4 Sedimentary rocks

□ 10.5 Metamorphic rocks

□ 10.6 Making 3D models of geologic features related to plate tectonics.

□ 10.7 Earthquakes.

To earn your Earth Processes badge, you need to complete at least 3 of the 7 activities. Check off all the activities you've completed. When you have earned your badge, sign below and have your FRA leader sign and forward this sheet to the AFMS Juniors Program chair.

____
Date completed

____
My signature

____
Youth leader's signature

____
Name of my club

Leader's preferred mailing address for receiving badge:

____

____

____

Back-up page 10.1: What is a rock?

Minerals ***are inorganic substances with unique chemical compositions created in nature.*** "Inorganic" means they're not alive. Minerals often produce crystals, and a particular type of mineral always has the same chemical make-up that gives it a distinctive crystal form and color/s. Minerals are the individual units or building blocks that, brought together, make up a rock. **Rocks** ***are inorganic solids from the earth's crust that are made up of one or more minerals***. To provide a comparison for kids, you might say that everyone in your club represents an individual mineral. You have boy minerals, girl minerals, mother and father minerals, etc. Scattered around town, each is an individual, but when you bring them together in the same room, the individual boys and girls and parents become something new: a rock club. Just so, when individual minerals come together in a group, they create a rock.

Granite is a good example for showing how rocks are made of collections of minerals because crystals of the individual minerals making granite are especially large and visible as compared to some other types of rocks. Although different types of granite will have different combinations of minerals, most granite is made of the minerals feldspar, quartz, mica, and hornblende. The quartz will tend to be clear or milky and shiny like glass. The feldspar might be white, gray, or pink and somewhat dull. The mica will appear as silver or black glittery flakes. And the hornblende will appear as black specks. Have your kids examine a specimen of granite under a magnifying glass to see the different types of minerals in order to gain an appreciation of how a rock is made up of different minerals that have grown together.

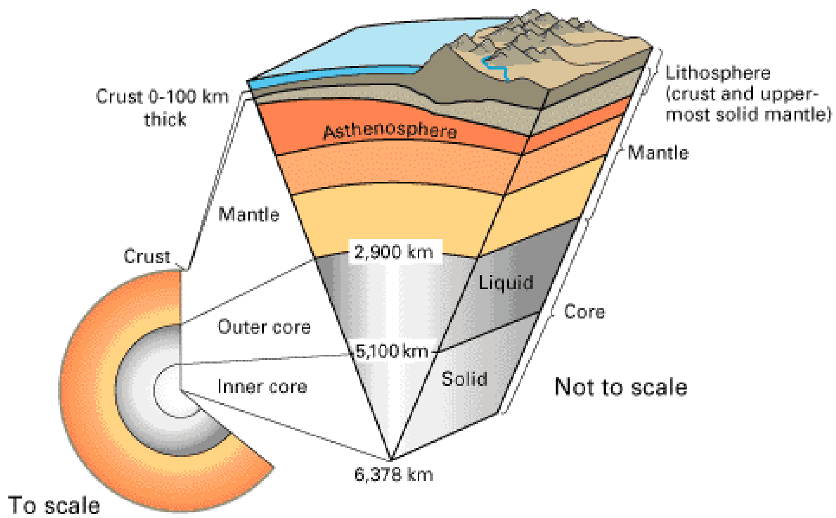
Rocks are divided into three groups:

1. **Igneous rocks** cooled and crystallized from hot, molten magma, either on the surface of the earth or deep below ground. "Igneous" is derived from the Latin word *igneus*, meaning "fire." Examples of igneous rocks your kids might collect include granite, basalt, rhyolite, obsidian, gabbro, tuff, andesite, pegmatite, or pumice.
2. **Sedimentary rocks** formed by gravel, sand, or mud that got buried and hardened due to pressure from overlying rocks. Sedimentary rocks start by processes of erosion that create gravel, sand, or mud that settles to the bottom of a basin (ocean, lake, or river valley) in layers. These layers eventually harden to become conglomerate, sandstone, or shale. "Sedimentary" is derived from the Latin word *sedimentum*, which means "to settle or sink down." Sedimentary rocks also include those that precipitate out of water, either through chemical action or evaporation, such as limestone, gypsum, or halite (salt). Examples of sedimentary rocks your kids might collect are shale, sandstone, breccia, conglomerate, limestone, coquina, diatomite, dolomite, travertine, or gypsum.
3. **Metamorphic rocks** are pre-existing rocks that have been altered by extreme heat and/or pressure to create a rock with a new form and mineral structure. "Metamorphic" is derived from the Greek word *metamorphōsis*, which means "to change" or "to transform." Examples of metamorphic rocks are marble, gneiss, slate, schist, quartzite, soapstone, greenstone, and serpentine.

Note: *Kids can use this activity to satisfy requirements toward earning their Rocks & Minerals badge (Activity 1.4) and Collecting badge (Activity 5.1) simultaneously.*

Back-up page 10.2: Plate tectonics and the rock cycle.

Some have described our Earth as a round soft-boiled egg with a partly solid/partly liquid hot **core** surrounded by a syrupy hot layer of soft rock known as the **mantle**, both contained within a thin and brittle outer **crust** of hardened rock.



Source: *United States Geological Survey website, "Education" link.*

On Earth, the rocks making up the crust are constantly moving through a cycle of formation and change through processes involved with **plate tectonics**. The thin, brittle crust of the Earth is not an even shell, as with our soft-boiled egg example, but rather, is cracked and divided into a number of plates that float and travel over the more fluid mantle. Much of the earth's seismic activity (earthquakes, volcanic eruptions, mountain building) occurs at the boundaries of these plates, where plates collide (as in the Himalaya Mountains), diverge (as along the mid-Atlantic ridge), slide past one another (as at the San Andreas fault), or where one overrides another (as along the east coast of Japan). Several web sites offer animations and/or instructions on making "earthquake models" so that you can demonstrate their effects and illustrate the different sorts of plate boundaries. For instance, see:

- "How to Make an Earthquake Model for Kids"
  www.ehow.com/how_5347246_make-earthquake-model-kids.html
- "USGS Science Fair Project Ideas"
  http://earthquake.usgs.gov/learn/kids/sciencefair.php
- "Earth Science 3D Paper Models and Toys"
  www.consrv.ca.gov/cgs/information/Pages/3D_PaperModels.aspx#heading

For photos of various earthquake events, you might check out the web site "Yup…Rocks," www.yuprocks.com.

As a result of these tectonic processes, with plates colliding, diverging, overriding, or sliding past one another, new rock is formed, old rock is worn down and re-deposited as sediment, and other rocks are changed through heat and pressure. You can use various types of rocks to illustrate this **rock cycle**.

- **Igneous rocks** formed from hot, molten magma, either deep underground (e.g., ***granite***) or extruded onto the planet's surface (e.g., ***basalt***). Igneous processes can form volcanoes and mountains that lift land up and create new land.
- **Sedimentary rocks**, on the other hand, result from processes that wear the earth down. Gravity, combined with the weathering properties of wind, rain, and freezing, disintegrates rocks, breaks them into smaller components, and transports them into valleys and basins as gravel, sand, or mud, where they pile up in layers and eventually harden into the sedimentary rocks known as ***conglomerate***, ***sandstone***, and ***mudstone*** or ***shale***. Sedimentary rocks also form chemically, as when calcium carbonate precipitates out of tropical seas to form ***limestone*** or when seas or lakes evaporate, leaving behind deposits of ***halite*** or ***gypsum***.
- Sometimes, igneous and sedimentary rocks get buried under other rocks and get caught up into immense forces involved in plate tectonics and mountain building. When this happens, these rocks get heated and squeezed, and the pressures can change their structures and transform them into whole new rocks, known as **metamorphic rocks**. These include rocks such as ***gneiss***, ***schist***, ***slate***, or ***marble***.

Here are some illustrations of how rocks move through a "rock cycle." Granite is an igneous rock that hardened and crystallized from molten magma deep beneath the earth. You'll see bits of crystallized quartz in granite. When granite weathers, these quartz crystals get worn down into grains of sand. When deposited in a valley, lakebed, or ocean, sand can harden into the sedimentary rock called sandstone. If the sandstone is buried and subjected to heat and pressure, it will transform into the metamorphic rock called quartzite.

Granite → Sandstone → Quartzite
igneous sedimentary metamorphic

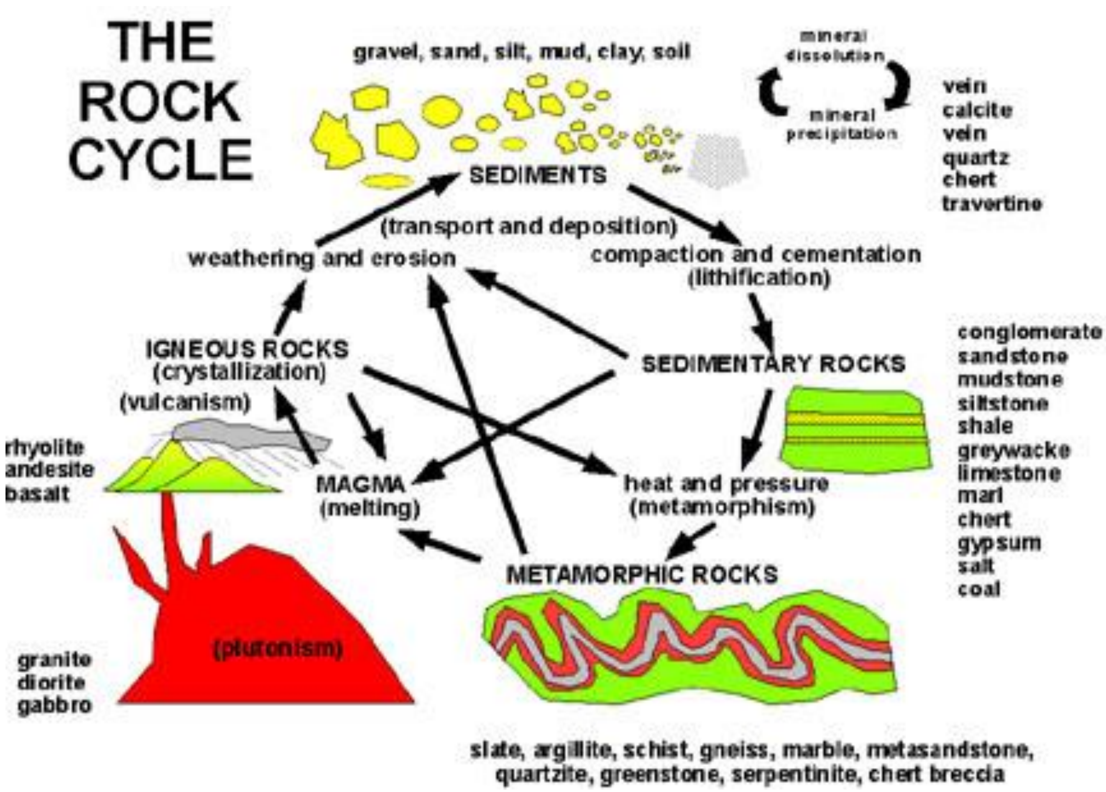
The mica and feldspar in igneous granite can get worn down into silt and clay. When that hardens, it becomes sedimentary shale. And when shale is subjected to heat and pressure, the original mica re-crystallizes to form flat, platy layers of metamorphic slate or schist.

Granite → Shale → Slate or Schist
igneous sedimentary metamorphic

To illustrate these processes, Abdo Publishing provides four great little books from their Core Library Rocks and Minerals series geared to kids in grades 3-5: Rebecca E. Hirsch's *The Rock Cycle* (2015), Lisa Owings' *Igneous Rocks* (2015), Rebecca E. Hirsch's *Sedimentary Rocks* (2015), and Jennifer Swanson's *Metamorphic Rocks* (2015). Check for details on these and other books at www.mycorelibrary.com. Oxford University Museum of Natural History has put together "The Learning Zone" website: www.oum.ox.ac.uk/thezone/rocks/index.htm. It provides fun sections geared to interactive learning as kids follow "Rocky" through the rock cycle.

Another helpful partner in educating kids about the earth sciences is Myrna Martin, who began a home-based business called Ring of Fire Science Company LLC in Oregon (www.RingofFireScience.com). Inspired by the eruption of Mount Saint Helens 90 miles from her home, she crafted a set of lesson plans on volcanoes that grew into a whole "Hands-on Science" series. These include *Rock Cycle: Hands-on Science*, which is beautifully designed and illustrated with easy-to-follow instructions for activities directly related to the rock cycle and the three rock types along with lesson summaries, quizzes, and vocabulary with definitions provided in an end-of-book glossary.

Here's a simplified diagram of the rock cycle. Your kids should be able to find other diagrams in geology books that they can get from the library or a bookstore or from sites on the World Wide Web. Have them create a large poster of the rock cycle in which they list different sorts of rocks they might expect to find at different points along the cycle. To create a three dimensional poster, they might glue small specimens of some of the different types of rocks alongside their lists.



Source: *United States Geological Survey.*

Back-up page 10.3.a) Igneous rocks: Demonstrating effects of cooling and gases.

Igneous rocks form from molten magma from inside the earth that cools and solidifies as it nears or reaches the surface. To show kids how a hot, liquid substance can become rock hard when it cools, here are a couple easy demonstrations.

A. Fast cooling versus slow cooling. As molten magma cools, crystals form. If the magma cools very slowly, those crystals have a chance to grow large. This is what happens in **granite**, an **intrusive igneous rock** that generally forms deep underground and takes an extremely long time to cool. If magma cools more quickly, crystals don't have a chance to grow as large, so the resulting rock has a smaller crystal structure. This is seen in **basalt**, an **extrusive igneous rock** formed from magma that rose to the surface of the earth where it cooled more quickly in the air. Sometimes magma cools super-fast, and when that happens, crystals may not have a chance to form at all, as seen in smooth **obsidian**.

If you have some available, use specimens of granite, basalt, and obsidian to illustrate this difference in rock texture and crystal size. Have kids examine each closely with a magnifying glass to see the differences and have them use their sense of touch to feel the different textures. **You can illustrate how crystals grow to different sizes depending upon how quickly they cool with the following experiment:**

Materials.

- Cooking pan with a half-cup of water
- Hotplate or stovetop
- Spoon and ladle
- Two and one-half cups of sugar
- Empty bowl chilling inside a larger bowl half-filled with ice cubes

Procedure.

1. Bring the water to a boil and slowly stir in sugar until you form hot syrup.
2. Ladle just a small bit of your syrup into the empty chilled bowl to cool quickly as a thin film on the bottom of the bowl.
3. Leave the rest of your syrup in the original cooking pan to cool slowly.

Once both mixtures have cooled, you should observe that the mixture in the chilled bowl is very clear and smooth, with only tiny sugar crystals having formed, whereas the mixture that cooled more slowly in the hot pan is coarser and lumpier and cloudy or milky looking. Similarly, magma that cooled quickly as lava on the surface of the earth tends to have smaller crystals and a more finely grained texture whereas granite, which cooled much more slowly as magma deep beneath the earth, tends to have large crystals and a very lumpy texture.

B. Quick cooling and the effects of gas bubbles. If magma cools super-fast, no crystals may form at all, and you end up with volcanic glass, or obsidian. **While we usually think of volcanic glass as being smooth and shiny, as you'll see in this demonstration, a little gas can make a big difference in texture and appearance.**

Materials.

- 3 cups of sugar
- 3/4 cup of light corn syrup
- 3 tablespoons of white vinegar
- 1/3 cup of water
- Butter or margarine
- Spoonful of baking soda
- Cooking pan and wooden spoon
- Candy thermometer
- Cookie sheet or shallow brownie pan
- Stove or hotplate

Procedure.

1. Grease the cookie sheet or shallow brownie pan with your butter or margarine and chill it in a refrigerator or over ice cubes.
2. Stir your sugar, corn syrup, vinegar, and water together in a cooking pan over high heat. Stirring constantly, cook to 302° F (150° C) on the candy thermometer, or "hard crack" stage. (Some candy thermometers will have this spot marked and labeled.) The ingredients should end up forming a hot, syrupy liquid.
3. Pour the thick syrup onto the chilled, greased cookie sheet or brownie pan and smooth it into a thin layer.
4. When the syrup mixture cools, it will become a hard lump. (In this case, it's a hard-candy lump that should be edible.)

Likewise, hot, soft, liquid molten magma solidifies into a hard igneous rock when it cools. In this instance, you will have created a smooth, clear "rock" with a texture somewhat like **obsidian**. Obsidian is lava that cooled very quickly, so quickly that crystals didn't have a chance to grow, thus resulting in smooth volcanic glass.

Another volcanic rock that cools to a glassy state is **pumice**, but unlike smooth obsidian, pumice is rough and porous. It's shot through with thousands of tiny bubbles from gases. These gases whipped up a volcanic "froth" that cooled quickly in the air. To illustrate this effect, you can follow the very same recipe outlined above but with the following twist. After pouring just half of your syrup into one chilled and greased pan or cookie sheet, set your cooking pan down and quickly stir a spoonful of baking soda into the remaining half of your mixture. The baking soda will react with the vinegar to release carbon dioxide bubbles throughout your mixture, which you should now pour into a second chilled and greased pan.

When both mixtures have cooled, shatter both into smaller pieces and have your kids compare pieces side-by-side along with specimens of obsidian and pumice.

Back-up page 10.3.b) Igneous rocks: Making a volcano.

The classic earth science project is making a model volcano that erupts with fluid lava. Here's how!

Materials.

- A 2-foot square sheet of poster board or plywood
- A small can (empty tomato paste or small mushroom cans work well)
- Newspaper, foil, or wire mesh
- Plaster of Paris, mixing bowl, spoon
- Water
- Paint, spray adhesive, sand, lacquer (optional)
- Baking soda
- Vinegar
- Red and yellow food coloring
- Dishwashing liquid
- Measuring cups
- Plastic film canister with a snap top
- Alka-Seltzer or denture cleanser
- Water
- Newspapers or drop cloth

Procedure.

1. On your poster board or plywood base, make a mound or cone shape from damp and wadded newspapers, wadded foil, wire mesh, or other suitable material.
2. At the very top, wrap this material around a small can or bottle.
3. Mix plaster of Paris (two parts plaster, one part water), and coat your mound with it, leaving the can open at the top. Then set it aside to let the plaster dry.
4. You can either use the volcano the way it is, or you and your kids can paint the volcano whatever colors you prefer or, for a realistic touch, apply a spray adhesive and sprinkle your volcano with sand (or glitter, for an artistic touch).
5. If you plan on re-using the volcano many times, you should coat the finished work with a lacquer so that it may be easily wiped clean.

You now have a dormant volcano. Here's how to make it active and ready to erupt in ways that will simulate two types of volcanic eruptions.

A. Lava flow eruption. Some volcanic eruptions are relatively mild. Rather than a single, massive explosion, they issue a flow of hot, basaltic lava, like we see with lava flows on the Hawaiian Islands or with the extinct cinder cone volcanoes and lava fields in the American West. Here's how to simulate this sort of eruption:

1. Place your volcano on newspapers or a drop cloth.
2. Fill the can at the top of your volcano one-third with baking soda.
3. In a separate cup, mix one-third cup of vinegar with a couple drops of red and yellow food coloring and two drops of liquid detergent.
4. Pour this mixture into your volcano with the baking soda to creating a sudden eruption and lava flow!

If you have specimens available, show kids samples of **basalt, pahoehoe**, or **a'a**. These are the sorts of igneous rocks formed in a lava flow like the one you've just demonstrated.

B. Explosive eruption. Other volcanic eruptions involve massive, violent explosions, like that which blew the top off of Mount Saint Helens in 1980. Here's how to simulate this sort of eruption:

1. Fill a plastic film canister three-fourths with water or vinegar.
2. Drop in an effervescent tablet (Alka-Seltzer or denture cleanser work well).
3. Quickly snap on the canister lid, give it a hard shake, and quickly place the canister into the mouth of your volcano, with the lid of the canister pointing up.
4. Keep kids back from the volcano as they wait. After just a second or two, the lid of the canister will pop several feet into the air along with a quick squirt of foamy water. (This works *very* quickly if using vinegar along with Alka-Seltzer, but may take a bit longer if using water with a denture cleanser tablet.)

If you have specimens available, show kids samples of **rhyolite** and **andesite**. These are the sorts of igneous rocks formed during an explosive eruption.

Making a plaster volcano can be time-consuming and involved and may require several days to complete in stages. It requires time for the plaster to dry, for decorating or painting the plaster, then for coating the volcano with a protective layer of lacquer and allowing that to dry. Here's an easier way for individual kids or pairs or teams of kids to make small erupting volcanoes of their own much more quickly.

Materials.

- Square-foot sheet of stiff cardboard (1 for each child or team of kids)
- Test tubes or small bottles (1 for each volcano being made)
- Clay or Play-Doh
- Baking soda
- Vinegar
- Red and yellow food coloring
- Dishwashing liquid
- Measuring cups
- Newspapers or drop cloths

Procedure.

1. With the cardboard as a base, kids position a small bottle or test tube in the middle.
2. Kids fill their bottles/tubes half full of baking soda, then pile modeling clay around the bottle in the shape of a volcano cone, leaving the top of the bottle open.
3. Mix vinegar with drops of red and yellow food coloring and a drop or two of dishwashing liquid.
4. Pour your vinegar solution into the baking soda to watch the volcano erupt!

For a wealth of information all about volcanoes, centered on the sorts of questions kids ask, a great resource is the little paperback book *101 Questions About Volcanoes* by John Calderazzo (Western National Parks Association, 1994, www.wnpa.org).

Back-up page 10.3.c) Igneous rocks: Collecting igneous rocks.

Following are igneous rocks kids may be able to collect if they live in the right area of the country, or that they may be able to purchase from rock dealers or to trade through the mail via the AFMS Patricia Egolf Rock Pals program as a club project with kids in other AFMS/FRA clubs who live in areas where igneous rocks are common:

- **Andesite** is a gray to black volcanic rock with a high silica content that commonly erupts as thick, sticky lava flows from stratovolcanoes, such as those in the Andes Mountains, which gave this igneous rock its name.
- **Basalt** is generally a hard, dense, heavy, dark gray or black rock formed from magma that flowed out of a volcano or vent in thick streams or sheets. Basalt can come in a variety of forms. **A'a** (pronounced "ah-ah") is variety that cooled with a jagged, rough and rubbly surface. **Pahoehoe** (pronounced "pah-hoi-hoi") cooled with a glassy smooth hummocky or ropy texture.
- **Gabbro** is a dark (often black), coarse-grained, intrusive igneous rock chemically equivalent to basalt but that cooled deep beneath the Earth's surface, resulting in large crystal structures within the rock that sparkle in the light.
- **Granite** cooled from magma deep under the earth and as a result usually has large mineral crystals all grown together. Depending on the type of granite, these minerals might include quartz, feldspar, mica, olivine, etc.
- **Obsidian** is a heavy, smooth, and shiny volcanic glass rich in iron and magnesium that cooled very quickly during an eruption, so quickly that crystals didn't have time to grow, thus resulting in glass. Chemically, it's often identical to pumice, which makes it terrific to use for compare-and-contrast with pumice.
- **Pegmatite** is a very coarse-grained igneous granite consisting of quartz, feldspar, and mica and commonly also containing large gemstone crystals such as tourmaline, aquamarine, and kunzite. Pegmatites form as a magma that cools quickly after intruding as a dike or sill into other rock.
- **Pumice** is formed from magma that shoots out during a particularly violent, explosive eruption. Gases dissolved in liquid magma expand rapidly during the eruption, making pumice extremely frothy (like froth created when you shake a soda can and open it). Millions of tiny gas bubbles leave cavities shot through pumice, making it extremely light—so light that it can often float on water!
- **Rhyolite** is often a banded light-colored, fine-grained rock that formed when thick, sticky lava flowed for relatively short distances.
- **Scoria** is similar to basalt, but whereas basalt usually flows in a thick, fluid layer from a volcano, scoria is shot into the air as a cinder during explosive eruption events. Thus, like Swiss cheese, it's peppered with holes from gas bubbles, making it much lighter than basalt.
- **Tuff** is volcanic ash and cinder that settles while still quite hot and becomes welded and compacted into layers of coarse, often lightweight rock that's usually white or gray or cream in color.

Note: *Kids can use this activity toward satisfying requirements for other badges, too: Rocks & Minerals (Activity 1.4) and Collecting (Activity 5.1).*

Back-up page 10.4.a) Sedimentary rocks: Making sedimentary rocks.

Sedimentary rocks start by processes of erosion that create boulders, cobbles, gravel, sand, mud, or clay. These settle to the bottom of a basin (low-lying land or an ocean, lake, or river valley) in layers. These layers eventually harden to become what are called "clastic" sedimentary rocks: conglomerate, sandstone, or shale. Sedimentary rocks also include those that precipitate out of water either through chemical action or evaporation, such as limestone, gypsum, or halite. These are "nonclastic" sedimentary rocks, or precipitates and evaporites. Via the following activities, kids can make artificial sedimentary rocks, including evaporites, sandstone, conglomerate, and breccia.

A. Creating precipitates and evaporites. Some sedimentary rocks, such as **limestone** and **gypsum**, chemically precipitated out of minerals in water or were left behind when water in a lake or sea evaporated. You can demonstrate this process using water solutions created with readily available materials.

Materials.

- Table salt, Epsom salt, or alum
- Water
- Measuring cups
- Spoon
- Cooking pan
- Glass jars
- Pebbles
- Stick or pencil
- String (cotton twine), cut into small lengths and dampened
- Food coloring (optional)

Procedure.

1. Heat water to a boil, then turn off the heat.
2. If using table salt, use ½-cup salt with ¾-cup hot water. With Epsom salt, use ½-cup salt with 1-cup water. If using alum, use ¼-cup alum with 1-cup water.
3. Slowly add and stir salt into the hot water until it becomes a "saturated solution." A saturated solution contains the maximum amount of mineral that will dissolve in a given amount of water. If all of your salt dissolves, the solution is not yet saturated, and you should add a bit more salt. Stop when no more salt will dissolve.
4. Optional: You can make colorful crystals by adding a couple drops of food coloring.
5. Place a few pebbles in a glass jar and pour your solution over the pebbles. Or, tie a piece of string to a stick or pencil. Dampen the string with your solution and roll it in salt to provide "seed crystals." Then pour your solution into a glass jar, and dip the string into the solution. Leave it hanging there from the stick or pencil.
6. Set your jar aside in a spot where it won't be disturbed and don't bump or bounce it. Check every so often the next few days. As water evaporates, you'll see crystals forming on your pebbles or string.

Assign different salts to different kids. Once everyone's water has evaporated, bring their jars together to compare the different forms of crystals each produced.

You can also grow crystals using commercially available crystal-growing kits from places like toy and craft stores, museum gift shops, or scientific supply houses. Two reliable supply houses are Ward's Natural Science (order their Earth Science and Geology catalogs; phone 1-800-962-2660; web site www.wardsci.com), or Edmund's Scientific (phone 1-800-728-6999; web site www.scientificsonline.com).

***Note:** Kids can use this activity for satisfying requirements toward earning the Rocks & Minerals badge simultaneously (Activity 1.6).*

B. Creating sandstone. **Sandstone** forms when sand is buried and mineral-rich groundwater flows through it. Minerals in groundwater act as cement to glue sand grains together while overlying layers of sediment exert pressure to compact it. Your kids can simulate sandstone formation with an easy activity to make their own artificial sandstone.

Materials.

- Paper cups
- Sand (from beach or hardware store)
- Epsom salt, sodium silicate solution (also called water glass), or plaster
- Water
- Pan or Pyrex measuring cup
- Spoon, dowel, or popsicle stick
- Food coloring (optional)
- Paper towels

Procedure.

1. Fill the bottom of a paper cup with a layer of sand about an inch deep.
2. Make a solution of mineral-rich "groundwater" in a pan or Pyrex measuring cup by dissolving Epsom salt in boiling hot water (keep stirring in salt until no more will dissolve). An alternative to Epsom salt is a sodium silicate solution (water glass) diluted with water. (As an option, have different kids add drops of different food colorings to their solutions to make sandstones of different tints.)
3. Pour the "groundwater" into the sand and stir it all together with a spoon, dowel, or popsicle stick to make sure all the sand is wet. However, you don't want to make soup, so don't pour in too much water!
4. Lightly tap the bottom of the cup on a countertop or desktop to settle the sand.
5. Set the cup, uncovered and undisturbed, in a sunny, warm open spot to evaporate the water. If you poured in too much solution, you may find you need to soak up excess water with wadded paper towels after you've allowed the mixture to sit for awhile.
6. After about a week, the mixture should have completely dried. When it has, tear off the paper cub, and you should end up with a rock that looks and feels similar to the sandstone in your sedimentary rock box.

I've had mixed success with using these Epsom salt and water glass solutions. They took a long time to dry, and Epsom salt often produced just a thin crust at the top of the sand. Here's an alternative that's worked with greater consistency. Fill cups with an inch-thick layer of sand and add a heaping tablespoon of plaster of Paris. Have kids add different food colors to different cups, and then add water and mix the sand and plaster together. This variation also tends to dry more quickly than Epsom salt or water glass solutions. In yet another variation, use two parts white glue to one part water. Mix this together with the sand in the bottom of your paper cup and allow to dry, then peel off the cup.

Kids will notice that the artificial sandstone is softer, crumblier, and not as heavy as the real thing. Ask if they can think of why. (Answer: the real sandstone not only has been cemented together by minerals in groundwater but also has been compacted when it was buried beneath other rocks. The weight of overlying rocks and earth pressures squeezed sand grains together as much as possible, forcing out air pockets and making the real sandstone much denser than our artificial sandstone.)

If you have specimens of real sandstone, you might notice that it comes in different colors, from yellow or brown hues to bright reds, grays, greens, etc. The color of sandstone may have two explanations:

i) Sometimes, sand grains are made of different minerals, and the color of the sandstone is caused by the color of the sand grains themselves. For instance, black sand beaches in Hawaii are derived from the dark basaltic lavas. White sand dunes covering an extensive area of New Mexico were derived from the mineral gypsum.
ii) Other times, the color of sandstone may be due to the color of the minerals deposited around sand grains by the groundwater. For instance, some groundwater holds iron oxide in it, and this will often cause a rusty color, "painting" the sandstone red.

Many times, the color of a piece of sandstone represents a combination of colors derived from the sand grains themselves along with the color/s of any minerals that were deposited around those sand grains to glue them together. You can demonstrate the coloring effect of minerals in groundwater by having different kids add different colors of food coloring to their ground water solutions. Have some add a couple drops of red, have others add a couple drops of blue, and have others use no food coloring and compare the resulting sandstones when all have dried.

C. Creating conglomerate and breccia. **Conglomerate** is a clastic sedimentary rock formed by the cementing of rounded cobbles and pebbles that have been worn smooth during transport in streams, rivers or ocean shores. The individual cobbles and pebbles (or "clasts") get compacted and cemented together in the same manner as sand grains in sandstone. **Breccia** is basically the same thing as conglomerate except that its cobbles and pebbles are sharp and angular, indicating that the rock fragments had not been transported very far before being deposited and buried. To make a conglomerate or breccia, you can follow a similar procedure as that used to make sandstone and just add pebbles to your sand mixture:

Materials.

- Paper cups
- Sand (from beach or hardware store)
- Gravel (both smooth and rough pebbles from a beach or river bed, or purchase bags of smooth and rough pebbles at aquarium supply stores or hardware stores)
- Sodium silicate solution (also known as water glass) or plaster of Paris
- Water
- Pan or Pyrex measuring cup
- Spoon, dowel, or popsicle stick
- Paper towels

Procedure.

1. Fill the bottom of a paper cup with a layer of sand and gravel about an inch thick. (Give half your kids rounded pebbles and the other half the rougher, angular pebbles.)
2. If using sodium silicate (water glass), make a solution of mineral-rich "groundwater" in a pan or Pyrex measuring cup by diluting the sodium silicate in water.
3. Pour the "groundwater" into the sand and gravel mixture and stir it all together with a spoon, dowel, or popsicle stick to make sure all the sand and gravel is wet. However, you don't want to make soup, so don't pour in too much water!
4. Alternatively, if using plaster of Paris, put a heaping tablespoon of dry plaster into each kid's cup of sand and gravel and then add just enough water to be able to stir and mix everything together. (Again, don't make soup!)
5. Lightly tap the bottom of the cup on a countertop or desktop to settle the sand, gravel, and water mixture.
6. Set the cup, uncovered and undisturbed, in a sunny, warm open spot to help the drying process. If you poured too much solution, you may find you need to soak up excess water with wadded paper towels after you've allowed the mixture to sit.
7. Once, the mixture has completely dried, tear off the paper cub, and you should end up with a rock that looks and feels similar to the conglomerate or breccia, especially if you break your artificial specimens in half.

Those kids who used the smooth, water-worn pebbles will have created artificial **conglomerate**. Those who used the rougher pebbles with sharp edges, on the other hand, will have created artificial **breccia**.

D. Creating a geologic column. The geologic column is the sequence of rocks that document the earth's ancient history. For instance, a layer of **limestone** that's capped by a layer of **shale** that's capped by a layer of **sandstone** might tell of a time when a sea began to retreat. When the sea was deep and clear, it left a deposit of limy, fossil-filled sediments that would eventually become limestone. But as the sea began to retreat and shrink away from its original banks, the floor of the sea would grow muddier from dirt washing in from the land and from swamps and estuaries advancing at the edge of the sea. This mud would eventually become a layer of shale. As the land continued its advance and the sea continued to retreat, a layer of sand from a beach might be deposited over the older layers of limestone and shale and eventually become sandstone.

Geologists study sequences of sediments like this from all around the earth. By studying sedimentary layers, they tease out stories each layer tells about earth history, and they assemble and organize various layers by time into the "geologic column," which is like assembling pages in a history book that progresses from ancient history to modern time.

You and your kids can create a small geologic column as follows:

Materials.

- Several cupfuls of sand and gravel
- Small seashells and thick leaves

- Petroleum jelly
- Waxed paper
- Plaster of Paris
- Water
- Food coloring (red, blue, green)
- Half-gallon cardboard milk carton
- Bowl or large plastic cups
- Spoon, dowel, or sticks
- Apron and paper towels

<u>Procedure</u>.

1. Cut the top off a half-gallon rectangular cardboard milk carton.
2. Spread your seashells and leaves across a sheet of waxed paper and lightly coat one side of each seashell and leaf with petroleum jelly.
3. Mix equal amounts of sand and plaster of Paris (about a half to one cup of each) in a bowl or large cup.
4. Add a few drops of red food coloring and water and stir to a thick, smooth consistency.
5. Pour this colored sand/plaster mixture into your milk carton.
6. Take some seashells and/or leaves and gently press them atop your sand/plaster layer with the oiled sides up. (Don't bury them completely into the sand/plaster layer; just nudge them in a bit, with the oiled tops showing.)
7. Repeat this process using sand/plaster layers colored by different food colorings (with some layers of no food coloring, just natural sand and plaster), placing oiled seashells or leaves between each layer as you build up a multi-colored "layer cake" inside the milk carton. For variation, in some of the layers you might mix in some pea-sized gravel along with the sand and plaster. Continue adding different colored layers until the milk carton is filled to the top.
8. Once the milk carton is full, let everything harden for a day or so.
9. When all is dry, peal off the milk carton to reveal your layers of sediment.
10. By tapping between layers with a hammer and chisel, you should be able to split your sedimentary rock into layers to reveal fossils and their impressions in the form of the seashells and leaves you dropped between layers.

<u>E. Observing sedimentation in action</u>. Rather than making artificial examples of sedimentary rocks, send kids outdoors to observe sedimentation in action. For example, they might see:

- rocks chipping off and piling up at the base of a cliff;
- a tree with roots growing into and cracking rocks and boulders at an outcrop (or buckling and cracking a cement sidewalk in their neighborhood);
- a gully cutting into a hillside and carrying away soil, sand, or gravel;
- sand bars and cobbles piling up in bars along a river bank.

Have kids look around and bring back lists of what they see in the natural environment, including these and any other examples.

F. Observing sedimentation in the lab. Kids can observe sedimentation in “the lab” with the following activities:

- Fill a large glass jar or water bottle one-third to one-half full of a mixture of gravel, sand, and dirt. Pour in water to the top of the jar and screw on the cap. Shake vigorously with up-and-down and circular motions. Then set the jar down and allow the mixture to settle. If all goes well, the sediments should have settled in clear layers by weight, with gravel on the bottom, mud on top, and sand in between.

- Fill a large pan with dirt and tilt it with a brick or wood block under one end. Using a gardener’s water can, rain water down from the high end to show how erosion occurs on hillsides, carving gullies and transporting sediment downhill with gravity. You might also plant stones in the dirt to show how such obstacles affect the flow of water and erosion.

- To illustrate the destructive power of water and how—given enough time—water can break down rocks as it expands and contracts between its frozen and liquid states, get a water bottle with a cap. Fill it one-third with cinders (available from the garden supply section of a hardware or garden store) and the rest with water. Cap it and pop it into the freezer. Over the course of several weeks, allow it to freeze and thaw a number of times. Finally, pour the contents into a bowl or pan. What began as cinder rocks should now be a combination of mud, sand, and cinders.

Back-up page 10.4.b) Sedimentary rocks: Making fossils.

Fossils are the remains of past life that got buried within sediments that turned into sedimentary rocks. This includes remains of animals (bones, teeth, shells) or plants (impressions of leaves or stems or petrified wood) or even imprints such as footprints that a dinosaur left on a beach or tubes that worms burrowed through mud.

Kids can make fossil imprints with clay and organic materials they bring in themselves, such as flowers, leaves, ferns, chicken bones, or seashells. Here's what they'll need:

Materials.

- Self-hardening clay
- Paper plates or sheets of waxed paper
- Rolling pin (optional)
- Seashells, leaves, chicken bones, flowers, ferns, or other organic materials
- Vegetable oil or talcum powder
- Paint (optional)

Procedure.

- Give each child a sheet of waxed paper or a paper plate and a lump of self-hardening clay.
- Either with their palms or with a rolling pin, have kids flatten their clay into a thin, even layer about a half-inch thick on the waxed paper or paper plate.
- Have your kids press their flower, leaf, fern, chicken bone, or seashell gently into the clay and lift it out. (With seashells that have deep ridges or indentations, they first may need to coat the shell lightly with vegetable oil or talcum powder to be able to lift it out of the sticky clay with ease.)
- Let the clay dry and harden, and each of your kids will have a fossil impression.
- For a realistic touch with impressions of ferns or other leaves, students can paint the impression with black, brown, or gray paint after the clay has dried. Most plant fossils are carbonized films, and the paint will replicate the film of carbon left on the impression.

Note: *For other, somewhat more involved projects to make fossils using clay and plaster, see the back-up page for Activity 3.2. You can use any of these activities to help kids satisfy requirements toward earning both their Earth Processes and Fossils badges simultaneously.*

Back-up page 10.4.c) Sedimentary rocks: Collecting sedimentary rocks.

Following are sedimentary rocks kids may be able to collect if they live in the right area of the country, or that they may be able to purchase from rock dealers or to trade through the mail via the AFMS Patricia Egolf Rock Pals program as a club project with kids in other AFMS/FRA clubs who live in areas where sedimentary rocks are common:

- **Breccia** is a clastic sedimentary rock composed of cobble- and pebble-sized rock fragments that are sharp and angular, indicating that the rock fragments had not been transported very far before being deposited and buried.
- **Coal** originated from compressed vegetation, often derived from swamps, that was buried rapidly in thick masses. High in combustible carbon content, coal-burning facilities are the largest source for generation of electricity.
- **Conglomerate** is a clastic sedimentary rock formed by the cementing of rounded cobbles and pebbles that have been worn smooth during transport in streams, rivers or ocean shores.
- **Coquina** is similar to conglomerate, but rather than being formed by rounded cobbles and pebbles, it's formed by masses of broken seashells, coral fragments, and other biologically-derived materials that are poorly cemented together.
- **Diatomite**, a soft chalk-like sedimentary rock, is composed primarily of silica from the fossilized shells of billions and billions of microscopic diatoms, which are algal-like organisms at the base of the ocean's food chain. It has many industrial uses as a filter (you'll see it in hardware stores with pool supplies), a mild abrasive, and as filler (as in house paints); under high magnification, the individual diatom shells look like snowflakes.
- **Gypsum** is a chemical sedimentary rock precipitated from highly saturated salt waters that left behind thick deposits of sulfate hemihydrate. Gypsum is the main ingredient in plaster of Paris and is also used in drywall, so you may well be surrounded by gypsum at this very moment.
- **Limestone** is a type of non-clastic, chemical sedimentary rock also called calcium carbonate because of its high content of calcium. It generally forms as a limy ooze precipitated on the ocean floor and includes shells from marine animals.
- **Sandstone** is a clastic sedimentary rock formed from the cementing of sand-sized grains, often from minerals in groundwater, along with pressure.
- **Shale** is one of the most common sedimentary rocks. It's composed of silt, mud, or clay that has been compacted to form a solid rock.
- **Travertine** is a form of calcium carbonate (like limestone) deposited through the action of water, such as mineral-rich springs. It's often soft and beautifully banded, making it a favored sculpting stone. It's also sometimes called onyx and alabaster.

Note: *Kids can use this activity toward satisfying requirements for other badges, too: Rocks & Minerals (Activity 1.4) and Collecting (Activity 5.1).*

Back-up page 10.5.a) Metamorphic rocks: Making a metamorphic rock with clay.

Metamorphic rocks are formed when pre-existing rocks (referred to as "parent rocks") are altered by extreme heat and/or pressure. This often creates a whole new sort of rock with a new form and mineral structure.

To illustrate how pressure along with heat can change a rock into something new, you can do a demonstration with clay that Lowell Foster of the Ventura Gem and Mineral Society of California has shared:

Materials.

- Bars of clay of various colors: red, blue, yellow, white, etc. (**Caution:** Use clays that may be baked hard in an oven. Be careful in selecting your clay because not all clays are suitable for baking, and some synthetic varieties might actually catch on fire! That's because some synthetics are made from petroleum products. Most clays available in craft stores indicate on their labels whether or not they may be fire-hardened.)
- Baking tray or pan
- Toaster oven or your home oven

Procedure.

1. If kids twist and press together a bar of blue clay with a bar of red clay with a bar of white clay, the pressure and the twisting make a new clay with a swirl pattern. (Before they start twisting, have them break off and set aside small pieces of their original clay for comparison at the end of this activity.)
2. The more you continue twisting and mixing, the more the pattern and color may change, with blue and red combining to purple in places, or red and white turning pink.
3. If you now add heat to the equation by baking your new clay, you'll get a hard ceramic-like rock with a swirl pattern. You can bake specimens in your own home oven or in a small, portable toaster oven if it's capable of baking at 265° F for 30 minutes or so.

The tough new rock that comes out of the oven will be very different in color, pattern, and texture from the three individual soft pieces of clay your kids began with. In a similar manner, metamorphic rocks end up changed in color, pattern, and texture from their parent rocks by the combined effects of pressure and heat. Have kids compare pieces of their original red, blue, and white clay alongside the lump of twisted, mixed, and baked clay.

To conclude this activity, you can use thin strips of clay of many different colors stacked atop one another and apply pressure from the sides and/or twist and turn to make wavy patterns, or press holes into yellow clay and insert small balls or squares of red or blue clay to see what happens to their shapes when you then press down. Give clay to your kids, and let them get creative!

Back-up page 10.5.b) Metamorphic rocks: Collecting metamorphic rocks.

Following are metamorphic rocks kids may be able to collect if they live in the right area of the country, or that they may be able to purchase from rock dealers or to trade through the mail via the AFMS Patricia Egolf Rock Pals program as a club project with kids in other AFMS/FRA clubs who live in areas where metamorphic rocks are common:

- **Gneiss** (pronounced "nice") is a "high grade" metamorphic rock derived from various sources (e.g., granite, shale, conglomerate, etc.) that were subjected to intense heat and pressure, heat so high that the rock nearly melted to a magma, resulting in minerals that drew together in distinct banding patterns under the high pressure.
- **Greenstone** is a fine-grained massive metamorphic rock with a dull luster that comes in varying shades of green; in California, it's associated with gold-bearing veins in the Mother Lode mining country.
- **Marble** is limestone that has been altered through metamorphic action. Soft, easily carved, semi-translucent, and capable of taking a polish, it's often used by sculptors and builders. Marble comes in various forms, depending on the elements contained in its parent rock. For instance, **limestone marble** contains mostly calcium carbonate and may have interesting veining (or "marbling") with colors due to different mineral impurities. **Dolomite marble** had a parent rock of dolomite, which is similar to limestone, but with magnesium in addition to calcite as a constituent mineral. And **mariposite** (named after Mariposa, California, where it occurs in abundance) is a form of dolomite marble with a high green chromium muscovite mica content that gives it a distinctive green marbling.
- **Quartzite** is a massive, medium-grained metamorphic rock with a sugary texture often derived from sedimentary sandstone.
- **Serpentine** is a fairly soft metamorphic rock that may be waxy to the touch and has apple-green to black, mottled coloring that can look like serpent scales. It's the official California State Rock.
- **Slate** is a "low grade" metamorphic rock (meaning it was subjected to only low heat and pressure) formed from sedimentary shale; it splits, or cleaves, in flat surfaces, and has been used as roofing shingles and blackboards.
- **Soapstone** consists mostly of an impure, massive variety of talc. Soft, with a pearly sheen, it's a popular sculpting material, but has many other uses, such as in the manufacture of laboratory tabletops, firebricks, and electrical apparatus due to its resistance to heat, electricity, and acids.

Note: *Kids can use this activity toward satisfying requirements for other badges, too: Rocks & Minerals (Activity 1.4) and/or Collecting (Activity 5.1).*

Back-up page 10.6: Making 3D models of geologic features related to plate tectonics.

It can be hard to fully understand some earth processes without visualizing them. The California Department of Conservation has stepped in to help in a hands-on way! Quite a number of folks and associations have come up with designs for crafting cut-and-fold 3D paper models to illustrate geologic features related to plate tectonics, including volcanoes, seafloor spreading and subduction, earthquake features and different types of faults (normal, reverse or thrust, strike-slip or lateral, transform, oblique, etc.), landforms and structural geology (synclines and anticlines, unconformities, etc.), and much more.

The California DOC has conveniently compiled these all together on a single website that describes each model then provides a direct link to the source where you can download and print masters for free to make copies for your club's kids. They note that the models exhibit better structure and stability when printed on cardstock. Here's the link:

http://www.conservation.ca.gov/cgs/information/Pages/3d_papermodels.aspx

This great resource provides cut-and-fold models you might use for still other badges. For instance, you'll find models illustrating the different crystal shapes of minerals for the Rocks & Minerals badge (Activity 1.5), models of a variety of fossils and dinosaurs that can be used when working on the Fossils badge (Activities 3.2 and 3.7), and models of the Earth and other planets that can be used when working on the Earth in Space badge (Activity 11.1).

Cutting out, folding, and gluing or taping engages kids in a hands-on way that provides a lot of fun while crafting a finished product that educates in the process!

Back-up page 10.7: Earthquakes.

Some parts of our continents are stable and the earth seldom moves under our feet. But at places like my home state of California along the edge of two major tectonic plates (the North American plate and the Pacific plate), the earth is anything but stable! Earthquakes are a daily occurrence somewhere in the state. Most are small-scale and go undetected except by monitoring stations with sensitive seismometers. But others can level entire cities. Here are some activities you can select from to do with your kids to explore earthquakes and their effects. Or, come up with earthquake activities of your own!

- **Modeling liquefaction.** When an earthquake hits an area that is sandy or covered with fine-grained soils or landfill, the effects can be devastating. To show why, fill a bowl with sand and set rocks on top. Flood the bowl with water then, very gently but rapidly, tap the edges of the bowl repeatedly. You'll see the rocks sink out of sight. Similarly, during an earthquake sand particles become suspended in water. The result is a lack of strength in the ground that allows buildings to subside and collapse.

- **Modeling effects on tall buildings versus short buildings.** Embed flexible metal rods of varying lengths into a section of 2X4 wood—for instance, a 6-inch rod, a 12-inch rod, and a 36-inch rod. Top each rod with a bolt or other heavy object. Then start shaking the 2X4. Notice the effects on the tallest rod versus the shortest rod. Similar effects happen with high-rise buildings versus low-rise homes. Which do you think will sustain the most damage during an earthquake?

- **Making models of different sorts of faults.** Construct 3D paper models of faults and other earthquake structures by going to the following website to get templates: www.conservation.ca.gov/cgs/information/Pages/3d_papermodels.aspx. You can also make models with thin stacked layers of play dough of different colors. Slice it at an angle and slide two blocks past one another or push together to see the results as one block rides up over the other. What are the underlying geologic forces and structures that cause earthquakes of different sorts and what are the effects?

- **Monitoring and reporting earthquakes.** With the Internet, everyone can help advance the science of earthquake monitoring and reporting. For instance, the U.S. Geological Survey (USGS) allows folks to go online and share information about the effects of any earthquake they experience to help create a map of shaking intensities and damage. Check it out on the web page called "Did You Feel It?" at http://earthquake.usgs.gov. On it, you'll be asked to rate earthquakes by answering such question as whether only dishes rattled or if heavy furniture overturned.

- **Major earthquakes throughout history.** Have kids select and research major earthquakes such as the San Francisco earthquake of 1906, the New Madrid earthquakes of 1811-1812, the Lisbon, Portugal earthquake of 1755, the Sumatra earthquake of 2004, or the Kobe, Japan earthquake of 1995. What caused each and what were the effects? How did they compare against other earthquakes? Can those areas expect still more earthquakes any time soon? If so, why?