Recording History

An Inquiry Unit on Rocks & the Rock Cycle

Byrd Polar Research Center, The Ohio State University
12/30/13

Teacher Notes
Background Information
Before starting this unit, it is important to establish relevance with students. There are different ways to do this, but here are two suggestions. First, most students have probably not considered the sources of many of the items they use on a daily basis. For instance, the food they eat and beverages they drink largely came from living things. The paper they are using and jeans they are wearing came from living things. This is also true of the material on fire in their wood-burning stove. But, what about the material that makes up the brick in their homes, the granite countertop in their kitchen, and the steel used in their car engine. Do they realize the source of many synthetic fabrics in their clothes, plastics in their mobile phone, and chemicals used in their hand lotion. All of these materials are harvested from the ground. We can call in mining or extraction, but the process is the same. These materials had to come from the ground.

Knowing a little about a rock can tell you a lot about its history. This is my second way of addressing relevance. A rounded granite boulder sitting in the middle of an Ohio farm field is a good example. Since it is granite, I know that the boulder formed from magma that cooled slowly under ground. The large mineral crystals in granite tell us that the magma cooled slowly, and the only place that it is possible to cool slowly enough is underground. Eventually, the surrounding rock eroded so that it was separated and able to be moved away from bedrock. Since the boulder is rounded, I know that there was some weathering, probably by water. If there had not been weathering, the rock would still have jagged edges. Now, granites bedrock is not found in Ohio. But, there are quite a few places with granite in Canada, and we know that glaciers moved down from Canada and then retreated about 14,000 years ago. So, the rounded granite boulder sitting in the field started as magma that cooled underground, was weathered by water, and traveled to Ohio on a glacier that then retreated. That is a lot of information from a rock; most rocks have a story to tell if people understand how to decipher the message. And, I could learn even more about the boulder I described if I had the time. I could study the minerals that make up the granite and better understand the composition of the magma. If I examine other rocks in the area, I could get a better sense of the complex history the area has experienced long before humans, writing, and video cameras where around to record it.

A number of terms are often used but students might not be able to put them in context or understand how they fit into the big picture of Earth's cycles. We strongly recommend that concepts are taught first with terms and definitions associated with these concepts following afterwards. It is important that well developed lessons allow students to experience a concept for themselves and build meaning. Otherwise, students often latch onto definitions without internalizing their meanings.

A few terms that students will encounter during this unit are rock, mineral, and soil. All materials are made of atoms. These atoms can come together in ratios to make minerals. For example, the mineral silica (also called silicon dioxide) has one atom of silicon for every two atoms of oxygen. Minerals can come in large sizes, the size of a car, or small sizes, too small to be seen without a microscope. The atoms in minerals are often found in certain arrangements that we call crystals. But the mineral must cool slowly enough when it is formed to allow the crystal arrangement to be built. If the mineral cools too quickly, a "glass" is formed. There is a connection with this concept and your everyday life. To make glass for your home or car, silica, a mineral crystal found in nature, is melted at very high temperatures, poured, and cooled quickly, over a few hours. If the mineral was melted, poured, and cooled more slowly, over a few months, crystals would form instead. So, "glass" is a scientific term for any mineral that is not formed into a crystal arrangement but we use it in common language to refer to glass made of silica.

Many minerals come together to form a rock. This is best seen in granite, such as found in many kitchen counters. In granite, you see black, white, pink, and maybe another color or two in the rock; each of these colors represents a different mineral. In granite, you will see many crystals of the same mineral spread throughout the rock. If when they are formed, minerals cool slowly, the crystals will be small. If when they are formed, minerals cooled very slowly, the crystals would be large. While the crystals in granite are large, in some rocks, such as basalt, the crystals are too small to be seen without a microscope.

Soil is probably the most common experience that students have with the solid part of the Earth (the lithosphere). But, it is a small part of the solid part. Soil is made of rock that is weathered into small pieces and combined with organic matter (matter than came from living things). The weathering can be freeze-thaw cycles or movement in water or wind that results in collisions with other rock. If the process happens for a short time, the collisions break the rock into pebbles. If the collisions happen over a longer period of time, we get sand (smaller sized pieces). If they happen for a very long time, we get clay (even smaller sized pieces). The organic matter in soil is material that came from plants or animals. For instance, decomposed leaves make up a larger part of the soil in temperature forests where they land each autumn.

The layer of soil we see and in which we plant crops is very thin and takes a long time to build up from weathering and addition of organic matter. In most places, it is a few tens to hundreds of meters deep. While this might seem deep, it takes hundreds to thousands of years to create this much soil. Below the soil is rock; we call this bedrock. You might have heard of a large building or bridge being built and pilings being driven into the bedrock. The bedrock is actual rock that underlies the soil. In some places, there is little if any soil and the bedrock sits at the surface. Soil is very important for plants to grow, and therefore ecosystems and humans.

While the rock cycle has traditionally been taught as memorizing a series of rocks and descriptions, this unit attempts to highlight processes in the Earth System and how scientists use rocks to learn about these processes. The array of rocks that are included is much smaller than typical. The belief is that students will understand more about processes when they have completed the unit, will better appreciate and understand a sample when they see it in nature or in a building application, and will be able to expand their knowledge from this foundation through their own investigations or further studies. We hope that simplification will lead to deeper understanding, much like biologists look at a few token cells to generalize cell structures rather than look at all of the cells types available in nature.

We will focus on the three groups into which scientists typically organize rock: igneous, metamorphic, and sedimentary. Scientists organize things into groups to make them easier to study. This is the same task that we remember from elementary school, sorting objects into groups with other objects that are more alike than different. The three groups are based on how the rocks originally formed. Igneous rocks form from magma underground or at the surface (it is called lava when it reaches the surface) that cooled to form a rock. Sedimentary rocks form from pebbles, sand, or clay that are deposited, buried, and cemented together by nature. Metamorphic rocks form when rocks that are already buried experience heat and pressure and change their composition through this “baking” process. (We do include sedimentary and metamorphic rocks that formed from the remains of living things as optional, but we do not include evaporates with sedimentary rocks for simplicity.) Scientists further organize each of the three groups based on the specific way that the rock was formed and the types of materials that make it up. At the end of this document, there is a list of excellent online resources. One of them, by the United States Geologic Survey, discusses the rock cycle in great detail.

There are a few processes that are important for students to understand at the end of the unit. The processes can be grouped based on the rocks that result: melting and solidifying (freezing**) results in igneous rock; weathering, deposition, and cementation results in sedimentary rock; and metamorphosis via heat and pressure results in metamorphic rock. An individual teacher needs to understand to what level their students need to understand these processes and the terms that they will apply to each.

*** Freezing is the process of going from a liquid to a solid. While we typically discuss this in terms of liquid water cooling to 0 degrees Celsius and becoming ice, magma cools at a much higher temperature into solid rock. Freezing refers to the process of a liquid transforming into a solid regardless of the temperature at which it occurs.*

While we have included two typical diagrams of the rock cycle below for the benefit of teachers, it might not be fruitful to show students this diagram at the beginning of the unit. There is research that showing students a pre-drawn diagram of the water cycle, without experiences to better understand the processes in the cycle, leads to oversimplification and superficial understanding.

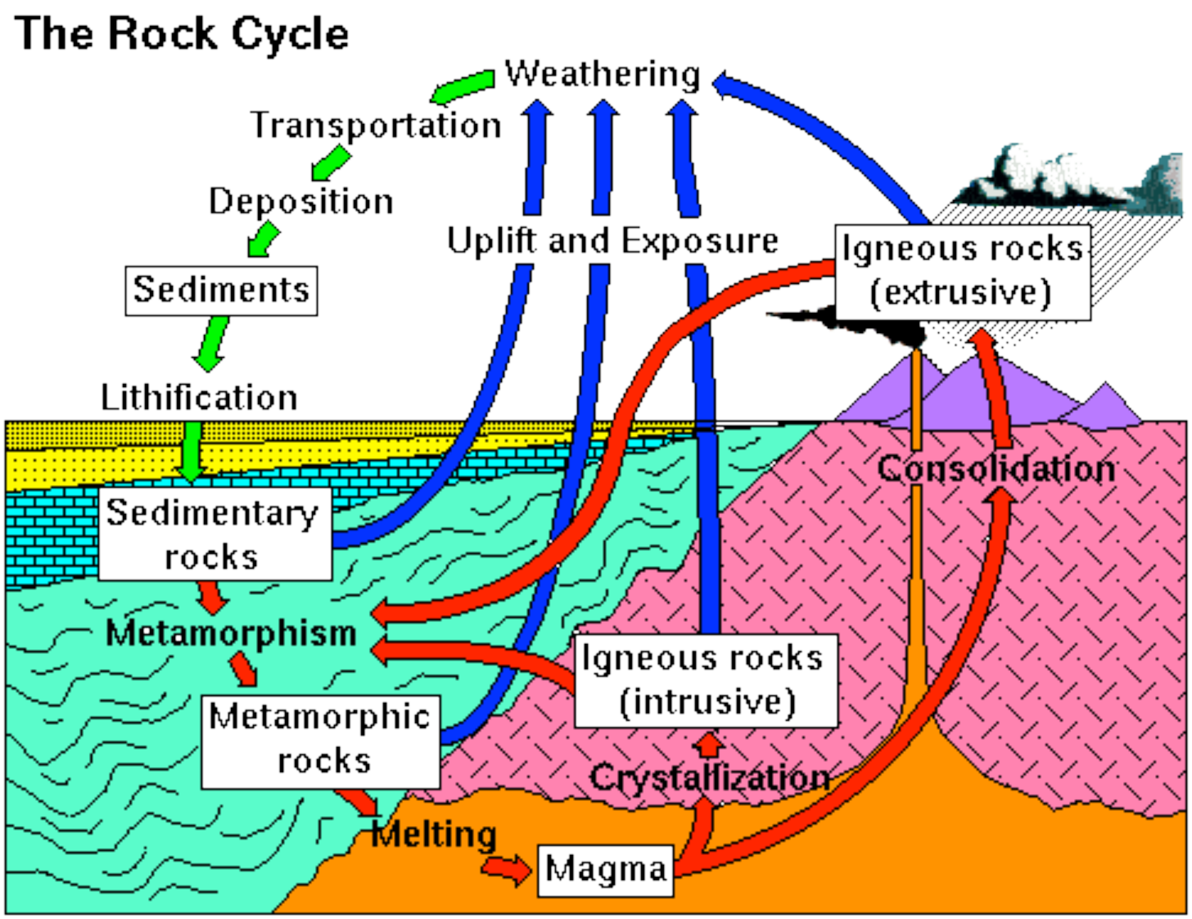

Image of the rock cycle provided by the University of Washington.

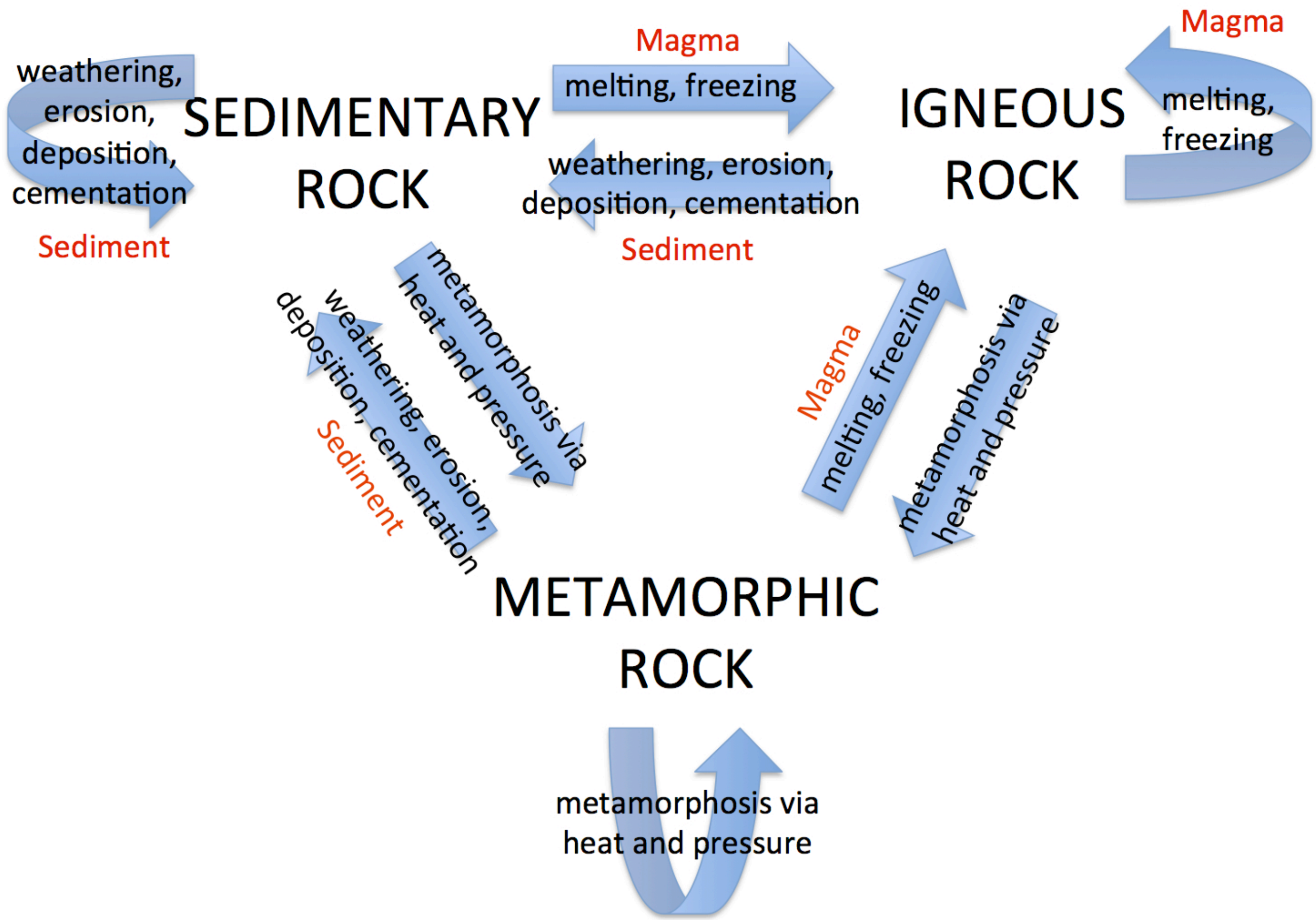

Image of the rock cycle depicting it less as a cycle and more as states of rock resulting from major Earth processes.

Recording History

Throughout this unit, there are many opportunities for students to write. We encourage students to keep a journal in which they can write, draw, and paste information. Depending on the nature of the class and age of students, the format of this journal can be open ended or more structured. This unit has been designed to promote investigation and understanding the process of science as much as delivering content knowledge.

Instructional Goals

- Rocks are important for understanding the Earth's past.
- Rocks are located beneath the soil and are a major component of the soil.
- Rocks provide clues about the conditions under which they were formed and existed.
- Processes on the Earth continue to reform a fixed amount of material from one type of rock to a different type of rock.
- Scientists organize rocks into categories, by how they were formed, to make them easier to study. These categories are igneous, sedimentary, and metamorphic.
- Heat and pressure can completely melt a rock to form magma or "bake" it to cause metamorphism.
- When magma cools, it solidifies (freezes) to form rock. The speed at which magma cools determines the type of rock that forms. The composition of minerals in the cooling magma determines the type of rock that forms.
- Different amounts of heat and pressure result in different degrees of metamorphism.
- Rock can weather into small or large pieces due to wind, water, or freezing, be moved by wind or water, and be deposited in low places.
- Rock that is weathered and deposited can be naturally cemented together once it is buried.
- Rocks can contain the remains of plant and animal parts.
- Rocks and materials produced from them are used daily for useful pursuits in society.

Beyond the Scope of This Unit

This unit does not attempt to discuss stratigraphy, plate tectonics, or the details of geologic processes such as erosion or volcanism. These are topics to be investigated in further detail in subsequent units.

Sequence

Investigation 1: What is a rock? What can we learn from it?

Investigation 2: Classify Various Rocks by Matching Samples with Their Corresponding Descriptions

Investigation 3: Sort the Rocks into "Useful Categories of Organization"

Investigation 4: Another Type of Sedimentary and Metamorphic Rocks

Activity 0: Rock Cycle Game

Activity 1: Concept Map the Rock Cycle

Activity 2: Identification of Processes

Activity 3: Background Reading, Electronic Media & Board Games (optional)

Activity 4: Crayon Analogy

Activity 5: Investigation of Antarctic Samples (optional: Making a Museum Display)

Challenge: Rock Sleuth

Fossil Fun (optional)

Field Experience (optional)

Overview

Investigation 1: What is a rock? What can we learn from it?

This introductory activity was inspired by School Yard Geology from the United State Geologic Survey (USGS). Pass out a variety of rock samples. These can be the same samples that will be used in Investigation 2. Ask students to discuss the characteristics of a rock or two with their partner. Once they have discussed, have them write down the characteristics they identified in their journals and then invite each group to share their ideas.

There will be some similarities between the ideas from groups. Some students might give exceptions to the ideas proposed by groups. This part of the activity is designed to start students thinking about rocks and their characteristics in addition to getting students making observations. It would be helpful to have a range of rocks at each table. It would also be helpful to bring in one larger sample or project an image of a large sample so that students can see that not all rocks are small. In fact, samples are typically broken off a large rock face when they are collected by scientists.

The second part to this investigation is asking students where they find rocks. Make a list on the board of places that students could find them or have seen them. Students will list a number of places, some are in nature (waterfalls, cliff, etc.) and other are in civilization (building, wall, yard). It is important that students understand that all rocks are found in nature and that humans often use rocks for useful purposes or decoration. We are able to cut rocks into regular pieces to build and crush rocks to create roadbeds. This is also a good time to discuss soil and rock below the soil (bedrock). Most younger students will not realize that that soil is made of very small rocks (microscopic) mixed with organic matter (broken up leaves for example) and that there is solid rock below the soil in their yard. There is more information about soil in the *Background Information*.

Realize, both sections of this investigation are informal yet critical ways to determining students' prior knowledge before proceeding with the rest of the unit. Time should be taken to carefully listen to student responses and circulate to hear small group discussions. Knowing where the students are when you start will allow you to better anticipate their needs later in the unit.

Byrd Polar provides Rock Boxes that teachers can borrow, free of charge, to use in their classrooms. The information for ordering is online at http://bprc.osu.edu/rr/rock_box/. Teachers can also purchase collections from science supply houses or create their own custom collection while travelling. If you are going to start your own collection, it is important to get a small brush and can of white paint to label your samples and create a key. Otherwise, you might quickly forget where you collected the sample and what type of rock it is.

Investigation 2: Classify Various Rocks by Matching Samples with Their Corresponding Descriptions
Part 1: Samples Include: Granite, Gabbro, Obsidian, Pumice, Conglomerate, Sandstone, Shale, Schist, Gneiss
During this first part of the Investigation 2, students will match a series of pre-written descriptions with the correct sample. We have included four igneous rocks, three sedimentary rocks, and two metamorphic rocks. A few key points are to be made through this investigation. First, students are using their observational skills to look closely at the samples and find an appropriate match. Each of the descriptions includes a discussion of how the rock was formed. Students will key in on this idea as they start Investigation 3 where they sort the samples. If not, teachers will need to guide students in this direction.

Of the igneous rock samples selected, two formed when magma cooled slowly underground, granite and gabbro, and two cooled quickly at the surface, obsidian and pumice. Of the granite and gabbro, the colors are different because the minerals in the magma were different. The two that cooled more quickly also had a difference in the composition of the magma (called lava when it reaches the surface). Pumice had gas trapped in it and obsidian did not. That is why you see the small openings in the pumice that make it look like a sponge. In fact, some pumice will float on water.

Of the sedimentary rocks samples selected, they are formed of different sizes of weathered rock cemented together (geologists call these rocks that are cemented together the grains). Conglomerate has large grains, sandstone has smaller grains (you might be able to make them out by looking closely, especially with a hand lens), and shale has microscopic grains.

Of the metamorphic rocks samples, one is further along in the process of metamorphosis. Schist is not as far along and will have smaller crystals arranged in faint bands (these bands might be hard to see but the rock will often break away in flakes). Gneiss will have larger crystals arranged in distinct bands.

Investigation 3: Sort the Rocks into "Useful Categories of Organization"
In this third investigation, students are asked to, "Sort the rocks into three categories based on the information that you have available." Students should be able to explain and defend the categories that they created. Groups will either focus on the appearance of the sample, the descriptions that they have been provided, or some combination of the two. The formatting of the wording on the descriptions provides some guidance. This is the same process that scientists go through; they sort objects into groups where the items are similar to ones within the same group and different than those in other groups.

Each group should whiteboard their classification system and the reasons behind it. Each group should have a chance to share their results; some discussion on the different systems might be necessary. At the conclusion of the discussion, students need to understand that for simplicity, scientists have elected to sort rocks mainly by how they were formed. We therefore have three categories: igneous, metamorphic, and sedimentary. But, scientists further subdivide the groups based on characteristics such as composition (the types of minerals that make up the rock). It is appropriate to acknowledge that other methods, such as those developed by students, could be used to sort rocks but in class we will be using the method adopted by scientists around the world.

Investigation 4: Another Type of Sedimentary and Metamorphic Rock

Part 1: Samples Include: Limestone, Marble, Lignite, Coal

Ask students to describe the differences they see between limestone and marble and between lignite and coal. Once they have done so, have them write their observations in their journals, both similarities and differences. It is important to point out that rocks are not the only things that can be deposited and cemented together. The remains of living things, plants and animals, can be buried and cemented together. Limestone is largely made of shells of ancient animals. Lignite is made of parts of plants that did not decay. If each of these is exposed to heat and pressure long enough, the limestone transforms into marble and the lignite transforms into coal.

The main point to this investigation is to expose students to sedimentary rocks that are made from living things being cemented together rather than smaller rocks being cemented together. Students might have seen fossils that came from limestone; these are particularly common in Columbus, Ohio. This investigation will help students create a more complex concept map later.

Part 2: Samples Include: Shale, Slate (optional)

Shale is a sedimentary rock that goes through metamorphosis to form slate. Slate can be broken into layers, which is why it was often used as a roofing material.

Activity 0: Rock Cycle Game

A great was to get students thinking about the continual transformations that the materials making up rocks undergo it to have them play the Rock Cycle Game (http://www.geology.ar.gov/pdf/RockCycleGame.pdf). While there are many versions of this game online, we prefer this one because of its simplicity and focus on processes. Students need to appreciate that while these processes are slow, they are happening continually. The Earth is dynamics rather than static. The teacher will need to provide each student with a log so that they can track their journey through the processes. Since it can get chaotic having students move around the room, we recommend placing the 5 stations around a large open space in the room, reminding students not to run, and providing multiple die at each station. Students will be able to use their log from the activity to help them construct the Concept Map of the Rock Cycle below.

Activity 1: Concept Map the Rock Cycle

Students should write the three categories igneous, sedimentary, and metamorphic on their group's whiteboard. They then need to draw arrows with labels between the categories explaining how the minerals can be "reformed" to create a different type of rock. There are many possibilities, but students should be guided by the labels from Investigation 2 and the log from Activity 0. After groups have shared their diagrams, the class should agree on one diagram. The teacher might need to add some processes. It is important to include the processes of weathering, deposition, cementation, melting, solidifying (freezing), and metamorphosis. The concepts are much more important than the terms. In fact, the terms should not be introduced until students understand the concepts and have seen examples of where each happens.

Activity 2: Identification of Processes

Student teams will look at a series of photographs or videos, identify which processes are shown (weathering, deposition, cementation, melting, freezing, metamorphosis), and the rock types that could result. They will need to share their reasoning for the processes and rock types selected. Realize that most photographs or videos will include more than one process and rock type; the student explanations are the secret to determining if the concepts are understood.

Activity 3: Background Reading, Electronic Media & Board Games (optional)
Background readings, electronic media, and board games are available to reinforce what students have learned. It is important to select materials that are at appropriate cognitive and reading levels for students. A number of excellent examples are included in the Resources section.

Students can also be challenged to develop a game of their own. Please note, this can be a time consuming task and requires a clear rubric to establish expectations while not limiting creativity.

Activity 4: Crayon Analogy
This activity has been presented in a number of locations. Students use crayon as a material to demonstrate the rock cycle. A well-written and thorough procedure is provided online at http://serc.carleton.edu/sp/mnstep/activities/26314.html. Students can be guided through the procedure or it can be used as a more open-ended task where students demonstrate their understanding by showing all three types of rock and the various processes using the crayon.

Activity 5: Investigation of Antarctic Samples (optional: Making a Museum Display)
All of the samples coming from Byrd Polar are catalogued at the Polar Rock Repository. Their "story" is available online at bprc.osu.edu/rr/ by using the Quick Search option. Type the number written on a sample (PRR-5617 for example) into the search box. You will get information on the location from which the sample was collected, notes made by the individual who collected the sample, the name of the person who collected it, and the year it was collected. Additional information includes the geologic period from which it originated.

This information can be used for students to investigate Antarctic geography. While most of the continent is covered by ice sheets and glaciers, there are mountain ranges and valleys. This might be an interesting way to start a discussion about geography, history (such as polar exploration or the Antarctic Treaty) for a social studies class, or geologic time periods. Students could identify the location of their sample on a map of Antarctica, calculate the distances from other locations, and determine the shortest route to collect a number of samples.

Please note, this activity could be used as an engaging way to conclude or start the unit. Students could be given a sample with the following challenge. "Your class has been asked to create a display of rock samples to share with families visiting a local nature center. Unfortunately, like most centers, there are more samples than there is space to display them. You need to create a compelling argument, with evidence, for why your sample should be included in the display." Students could create their own display with a caption, background information, and video.

If this activity is done as an introduction, the focus is more to excite students about the diversity of samples and the various conditions under which they originated. It is not critical for students to understand all of the geology as this will be revisited in investigations and activities that follow.

Challenge: Rock Sleuth

Students will use the knowledge and skills they have learned thus far in the unit to identify eight unknown samples. This serves as a lab practicum with students working in small teams to apply their learning. If students have kept journals, they should be allowed to use them. The unknown samples should be similar to but not identical to the rocks used in Investigation 2. The age of the students will determine how difficult the teacher should make this challenge.

Fossil Fun (optional)

A simple task for students of all ages is to provide each small group with a collection of fossils. The group needs to name a living thing that the fossil most resembles and provide two to three specific characteristics that led the group to this conclusion. The difficulty of the fossils presented can vary depending on the age and experiences of the group. For instance, the following list would be appropriate for an elementary school audience: leaves, wood, snails, clams, and coral. Fossils of extinct species could be included, ammonites and trilobites for example. For younger audiences, a list of the names of the living things or photos/drawings might need to be provided. This activity is about making observations, matching those observations, drawing conclusions, and communicating information. It is important not to overwhelm students with too many poor-quality fossils that in no way resemble the living thing from which they came.

Discussions about fossils can include which parts of the living thing are preserved (hard structures that generally do not decompose versus soft structures that do) and the processes that replace one mineral with a different mineral in the hard structures. In fact, a special series of events needs to take place for us to see evidence of past living things in fossils. First, the living thing needs to die and be buried in a place where it is neither physically destroyed nor decomposed. Second, a process needs to occur that preserves the appearance of structures of the living thing (the mineral replacement described above is an example). Third, the fossil needs to be at a location where we later find it (generally at the surface), such as a natural rock outcrop or a road cut. While there have been many living things on Earth over the past 4.5 billion years, only a small percentage of them have followed this process that has resulted in them being transformed into a fossil that finds its way into human hands.

This activity could be a departure point for a discussion about adaptations for specific environments.

Field Experience (optional)

Geology is most interesting and exciting when students can get outdoors to experience it firsthand. Your school might have an outdoor space where there are rocks. If not, check with your local park service or state department of recreation for local places where students could experience concepts from this unit firsthand. Most outdoor professionals will be happy to brainstorm ideas or help facilitate programs with groups of students.

Resources

- Annenberg Learner. Interactives: Rock Cycle. Available online at http://www.learner.org/interactives/rockcycle/index.html.
- Arkansas Geological Survey. Rock Cycle Game. Available online at http://www.geology.ar.gov/pdf/RockCycleGame.pdf.
- BBC. KS3 Bitesize. Available online at http://www.bbc.co.uk/schools/ks3bitesize/science/environment_earth_universe/rock_cycle/revise1.shtml.
- Polar Rock Repository, Byrd Polar Research Center. Rock Box Order Form. Available online at http://bprc.osu.edu/rr/rock_box/.
- Schaffran, J. Earth History: Crayon Rock Cycle. Available online at http://serc.carleton.edu/sp/mnstep/activities/26314.html.
- United States Geologic Survey. School Yard Geology. Available online at http://education.usgs.gov/lessons/schoolyard/.
- University of Washington. The Rock Cycle. Available online at http://www.washington.edu/uwired/outreach/teched/projects/web/rockteam/WebSite/rockcycle.htm.htm

Please note that a number of iPad applications have been developed recently with spectacular geology imagery.