Get to Know Rocks and Minerals

60 Rock and Mineral Specimens

with activities for Primary, Elementary and beginning Earth Science studies for middle and high school students.

Includes lesson plans, card materials, experiments and charts.

Look at everything you get with this kit:

60 Identified Rock and Mineral specimens
24 activities for primary students; 50 activities for elementary or beginning earth science students
Lesson plans for the activities
Card Material to accompany lessons and activities
Charts and graphs to go with lessons and activities

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Rocks and Minerals:
A Note on Lesson Plans and Activity Design

When I create lesson plans, I do it with several thoughts in mind. Of course, I first think of the students who will view the lesson, but I also think of how the students will use the information AFTER the lesson. I try to make sure there is shelf work available so students can investigate independently. There is almost always some sort of follow up that can be completed immediately after the lesson or over time at the student's discretion. Sometimes it is an assignment, but usually I try to make the lessons pretty exciting so the students will feel compelled to be first on the list for follow-up opportunities!

I focus on the main concepts to be presented, but I also include other skills such as graphing, classification, decision-making, problem-solving, etc. Sometimes my lesson seems to be about rocks and/or minerals, but it is truly more about adjectives or percentages. The students don't necessarily know this, but when they are interested and engaged their peripheral learning can go VERY deep! You will see a list of both direct and indirect aims at the beginning of each lesson plan, so you can see some of my thoughts on the various skills I'm going for in each lesson.

Generally, the lessons are intended for a group of 4 to 8 students who could sit in a circle around the teacher either on the floor or at a table group. I like to keep the students close so they can touch, smell, and see. That keeps their interest, but it also allows me to interpret their understanding more accurately.

One could also adapt the lessons to be given to a large class of up to 25 or 30 students. However, if this were the case, I would try to have the students sit in groups of 4 or 5 around tables that have all the materials available to the smaller group.

If I were "brainstorming," I might go through the process with the entire group for a moment as an example. I'd write their thoughts on chart paper or a dry erase board, then have the students transfer the ideas to individual cards or papers. Once they had accomplished this and were showing understanding, I'd have them continue on their own within the small group.

With the sorting work, every group would need their own set of rocks, but the rocks would not need to be the same. In fact, it would be fun to see how different small groups would group the rocks differently. It would inspire good communication and discussion.

There is nothing magical about these lesson plans, except that they are done and ready to use! When we decided to provide a rock and mineral collection, we remembered that too often we were offered lovely collections with no plans to help us. Before we became so involved in our geology work, that missing support held us back. This e-book includes lesson plans, but also printouts of the paper materials you will need to do the lessons. We've tried to include as much support as possible.

If you ever have questions or experiences to share, please drop us a line. We'd love to hear how the lesson plans are working for you!

Here's to you having fun with Rocks and Minerals!

Claudia and Doug Mann
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Acknowledgements

There have been many inspirations on the path toward completion of this curriculum. I want to acknowledge all the teachers who have encouraged us to keep working so they will have a resource that allows them to open up the world of geology to their students who are enthralled with it. Kathy Koenig, who worked with us as she started an after school geology club, has shared so many insights and ideas that have inspired. Thank you to all the children in our classes whose interest in fossils and minerals kept us seeking new and better ways to share the wonder of earth science, especially Wiley, Matthew and countless children from all around the globe who have contacted us with their questions and enthusiasm.

Thank you to Doug whose vision has guided all our efforts. Your faith and encouragement got this finished…even though it took much longer than you would have liked. I hope it was worth waiting for! Your patience and your encouragement always sustain me through the tough times.

Claudia Mann
November, 2008

Section 1: Lessons for Primary Classrooms
(Students Ages 3 through 6)

To the Primary or Preschool teacher:

Children are fascinated with the natural world and all its wonder! Time and time again, I have answered the question, “What rock is this?” from a four-year-old who is drawn to the tiny sparkles contained in a rock, the vivid white bands that flow through another, or the stunning color of another. Pre-school children are drawn to detail. Through their eyes, I have seen things never-before perceived: a tiny, unique grain or a picture of a flower! Just opening their senses to the world of rocks and minerals is a great gift you can give to your students!

The set of rocks and minerals you have purchased from Fossilicious.com is organized and packaged by type: igneous, metamorphic, and sedimentary and minerals. The set contains pairs of rocks and minerals so you can design the matching work to meet your students’ needs. You may use the lessons in this e-book with various types of rock and mineral specimen kits.

Your awareness of your students’ particular observation skills will guide the specimen choices you introduce at a given lesson. As the students’ discernment skills increase, you can increase the level of difficulty. Choose the number of specimens to present based on the age and ability levels of your children: no more than three at a time for the youngest children and up to six for the oldest.

We suggest that you begin working with these materials in sets of rock types, beginning with igneous, followed by metamorphic, then sedimentary, and finally, minerals. The rationale behind this is that children will begin to recognize the rocks of each set as “going together.” This will prepare their awareness for later identification of the rock groups: igneous, metamorphic and sedimentary, and will help them begin to observe the difference between rocks and minerals.

There are a number of ways you can use these rocks in your 3-6 or preschool classroom. We have written a few lesson plans, but these can be infinitely varied by changing the particular rocks or minerals used. If your children take you to the more advanced lessons; go for it! There are a few lesson plans that could fit easily into both preschool and elementary levels.

The presentation style for these lessons follows a Montessori approach, introducing no more than 3 specimens at the initial presentation, using minimal language, and allowing the student to create his or her understanding as he or she works with the materials.

Once a presentation is given, the rocks can be placed on the shelf in a basket for the student to choose at her own discretion. A specially prepared box with compartments is also a possibility and you may add nomenclature cards that name the rocks as your children become increasingly familiar and are emerging as readers.

We hope you’ll have a great time introducing these rocks to your students, extending the work with new lessons, and, above all, taking your children out to find the particular rocks and minerals where you live.

Matching

Direct Aim:

- To exercise and increase a child's ability to notice distinguishing characteristics of different types of rocks and minerals.

Indirect Aims:

- Organizational thinking, discernment and classification: learning how to sort, organize and distinguish characteristics of any group of objects.
- To learn that there are different types of rocks and minerals.
- To learn the different nomenclature and vocabulary associated with the different types.

Materials:

- A selection of rocks or minerals

Lesson

Note: Use specimens from the same basic group: igneous, sedimentary metamorphic, or mineral.

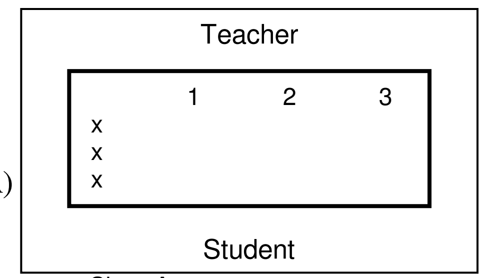


Chart A

1. Take the first specimen (ex. basalt) and place it on the left side of the rug. (oriented to the Student, placed in location #1 as in chart A)

2. Take the second specimen (ex. obsidian) and place it next to the first specimen. (location #2)

3. Take the third specimen (ex. scorria) and place it next to the second (location #3)

4. Take the three matching specimens (x,x,x) and place them to the far left side of the rug in a column, placing the third specimen on top.

5. Pick up the top specimen from this column and move it under each of the initial three specimens, moving from left to right. When you arrive at the matching specimen, leave it under the matching specimen. This is done without speaking.

6. Continue with each of the remaining specimens.

7. Allow children to practice before leaving the lesson.

8. Place the rocks in a basket on the shelf so the children may choose them and set up their own matching practice.

    - Further lessons can add different types of rocks or minerals, expanding the student's vocabulary and indirect preparation for rock types, mineral types, etc.

Grading

Grading is the procedure used to put a group of items in order according to a particular characteristic. The teacher is limited only by her creativity in finding particular characteristics to grade. The exercise can be made more challenging by choosing specimens that have small differences in grade or by having more than three specimens to grade.

Direct Aim:

- To exercise and increase a child's ability to notice distinguishing characteristics of different types of rocks and minerals.

Indirect Aims:

- Organizational thinking, discernment and classification: learning how to sort, organize and distinguish characteristics of any group of objects.
- To experience different types of rocks and minerals.
- To learn the vocabulary and suffix patterns associated with making comparisons.

Materials:

- A selection of rocks or minerals

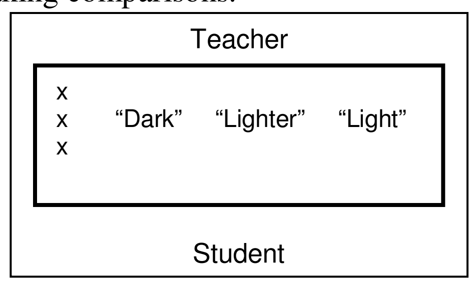


Chart B

Lesson

1. Set three specimens on the left side of the rug. (The specimens should be a range from dark to light.)

2. Pick up the dark specimen and place it on the rug, to the student's left. Say, "Dark."

3. Take the medium colored specimen and place it next to the first specimen. Say, "Lighter."

4. Take the remaining specimen and place it next to the "lighter" specimen. Say, "Light."

Note: You could also begin with the Light specimen and label the medium specimen as "Darker" and end with "Dark."

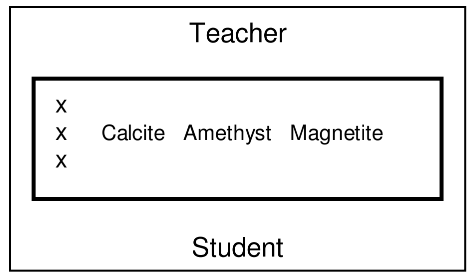
- Further lessons could include different specimens, but still using dark to light, or the lesson could involve more specimens to grade from light to dark, rough to smooth, dull to shiny, small grain size to large grain size, or heavy to light weight. For heavy to light, make certain the specimens are of nearly the same size and shape.

Naming

Student ages 3 to 6 are in a sensitive period for the acquisition of language. By choosing rocks or minerals with very different visual characteristics, the teacher can support the child to learn the names of many different rocks and minerals.

Direct Aims:
- To exercise a child's ability to notice distinguishing characteristics of different types of rocks and minerals and use them in naming or labeling the specimen.
- Acquisition of Language through naming of rocks and minerals

Indirect Aims:
- Organizational thinking, discernment and classification.
- To experience different types of rocks and minerals.



Materials:
- A selection of rocks or minerals
- (Optional) Labels for writing the names

Lesson:
1. Set three specimens on the left side of the rug. (at x positions)
   (The specimens should be unique unto themselves and very different from one another.)

2. Pick up a specimen and place it in the middle of the rug.
   Say, "This is Calcite." (Name the mineral or rock you are choosing to use.)

3. Take a second specimen and place it next to the first specimen.
   Say, "This is Amethyst." (Name the mineral or rock you are choosing to use.)

4. Take the remaining specimen and place it next to the other specimens.
   Say, "This is Magnetite." (Name the mineral or rock you are choosing to use.)

5. Review the names of each by pointing at each specimen and saying only the name.

6. When the children seem ready, continue the lesson by asking, "Can you show me Calcite? Can you show me Amethyst? Can you show me Magnetite?" Continue this guessing game, mixing up the order.

7. When the children seem ready, continue by pointing to a specimen and asking, "What is this?"

   - As the children become more comfortable with naming the specimens and are beginning to recognize symbolic language, you may write the manes on slips of paper and allow them to match.
   - Further lessons can include different specimens, adding to the child's repertoire of vocabulary for rocks and minerals.

Volcanoes Make Mountains

Direct Aims:

- To show that volcanoes form mountains

Indirect Aims:

- Preparation for landforms
- Preparation for later work with volcanoes

Materials:

- Photographs of volcanoes from around the world (See appendix for photographs of a few or check http://vulcan.wr.usgs.gov/Photo/framework.html
- (Optional) A world map to show where the volcanoes are located (not included)
- (Optional) Signal dots for marking the locations

Lesson

1. Show a photograph of an erupting volcano.
2. Say, "Do you know what this is?" (a volcano)
3. Say, "How did you know?" (It is erupting. etc.)
4. Show a photograph of lava flowing (ex. from Hawaii)
5. Say, "Do you know what this is?" (. I can see the lava flowing. etc)
6. Show a photograph of a dormant volcano.
7. Say, "Do you know what this is?" (a mountain.)
8. Say, "Once this was an erupting volcano like this one," and show the first picture.
9. Say, " Many mountains were formed from volcanoes."

Optional continuation

10. Lay out pictures of three dormant or extinct volcanoes. (Ex. Ft. Fuji in Japan, Mt. Rainier in Washington, USA and Acatenango in Guatemala)
11. Say, "These mountains were all once active volcanoes. This is (name the mountain) and it is located in (name the country.) This is where it is located. (show location on the map and mark it.)
12. After the lesson, you may hang the map and the photographs connecting the photograph with their location with string or yarn.

Igneous Rocks Come from Volcanoes

Direct aims:

- To introduce the concept that only certain rocks are produced by volcanoes

Indirect Aims:

- Preparation for landforms
- Preparation for later work with volcanoes
- Preparation for understanding that rocks are formed in different ways.

Materials:

- A few photographs of lava flows or volcanic mountains
- A selection of igneous rocks

Lesson:

1. Show the photographs of the volcanoes you showed in the previous lesson.
2. Ask, "If you were to dig on this mountain, what would you find under the grass?" (dirt, rocks, etc.)
3. Show the igneous rocks.
4. Say, "These rocks were made by volcanoes."

Depending on the experience of your students, you might discuss how they were formed. Show the pumice or scoria and say, "This rock has lots of holes. That is from the gas that comes out of a volcano," and so on, using the information cards that came with your set of rocks.

Section 2: Earth Science Concept Lessons:
Background for the Rock and Mineral Lessons
(Students Ages 6 through 12+)

Depending on the ages of your students, you might want to consider presenting the foundation or background lessons prior to the work directly with plate tectonics or the rocks and minerals. However, this is not absolutely necessary. Many of the lessons will stand on their own within the context of a study on a particular subject. For example, you could decide to just focus on the types of rocks and allow the various ways that rock is formed to guide the study into volcanism or plate tectonics. Alternatively, you may have a plan to study clastic sedimentary rock, so a lesson on weathering would be good preparation.

The lessons themselves are not geared to a particular age child, although generally the language used is intended for an elementary student between the ages of 6 and 12. With some variation, however, certain lessons could be given to younger students (especially the volcano or weather lessons) and all could be used with older students who lack experience with earth science topics. Some of these lessons were tested on students in grades 7 through 9.

The lessons could be used in after school programs and geology clubs, too. You would most definitely want to focus on the more “hands on” lessons, but nearly every lesson offers that possibility.

Layers of the Earth

Direct Aims:
- To give an impressionistic lesson of the composition of the earth
- To learn the names of the various layers of the earth

Indirect Aims:
- Preparation for discussions of plate tectonics, magma, and different rock types

Materials:
- An onion
- Knife and cutting board
- Dilute blue food coloring on a saucer
- Labels for the parts of the earth as indicated on the chart.
- Chart of Layers of the Earth

Lesson: (Note: Italicized words are suggestions for language to use during the lesson.)

This onion is going to represent our plant, Earth. Why do you think it might make a good model? (Round)

Yes, it's round, but is a more important way that this onion is like the earth. It has layers.

We live on the outer-most layer of the earth. It is like the skin on the outside of the onion. Compared to the other layers, this outer layer is very thin and it is brittle.

Cut the onion in half across the layers and cut off the stem end. Then place the cut side face down on the saucer with the blue food coloring. The food coloring will help to show the layers.

Look at the rings. These layers are like the layers of the earth.

Push out the center-most section of the onion.

*This part that I have pushed out is the **core** of the onion. The earth also has a core. It is called the **solid inner core.** It is made of iron.*

Push out a few rings, discussing each layer, and label the **liquid outer core, lower mantle, upper mantle, and the aesthenosphere, and the lithosphere. (The aesthenosphere is the plastic outermost layer of the mantle and is the connecting boundary between the lithosphere and the mantle.)**

*The layers of the earth are extremely hot and, for the most part, they are liquid. The **mantle** has an oozing consistency that supports the lighter crust or **lithosphere**, on the top. Between the mantle and the crust is a layer called the **aesthenosphere**. It is plastic in consistency and is the connection between the crust and the mantle.*

The crust of the earth is brittle. The continental crust is the part that we can see as land when we look at the earth. The oceanic crust lies under the ***hydrosphere****: the layer of water that covers the lithosphere.*

All around the solid earth is a protective blanket of air called the ***atmosphere****.*

Show the chart.

This chart shows the earth in a cross section, just like our onion. The layers of the earth are labeled with their names.

For more detailed information, see the following websites:

> **http://www.glossary.oilfield.slb.com/DisplayImage.cfm?ID=124**
>
> **http://oceansjsu.com/105/exped_commotion/5.html**

Follow up

1. Students can color their own chart
2. Make models of the earth's layers using clay.
3. Make their own model of the earth using an onion and labeling the layers using little flags made of toothpicks and paper labels.

The Eight Basic Elements of the Earth

This is a more conceptually advanced lesson. It can be modified for younger students to simply make the impression that all of the millions of substances on earth are made up primarily of just 8 elements.

Students are introduced to the concept of an element. Students will work with the Periodic Table of the Elements and symbols of the elements. Additionally, students will present their data in the form of both bar and circle graphs.

Direct Aims:

To introduce the names of the eight elements that make up most of the earth's crust.
To give an impression of the percentages of these eight elements
To create different types of graphs to represent the quantities

Indirect Aims:

To give the students an experience with the Periodic Table of the Elements
To introduce the chemical symbols of the elements
Work with percents and decimals
Work with various types of graphs to represent the quantities

Materials needed for the lesson and follow-up work

Chart showing the layers of the Earth
100 marbles divided into the following colors:

Note: Two options are given for demonstrating the quantities. If you want to demonstrate portions, break marbles into approximate sizes as shown. But you could also round to whole marbles as given in parentheses. Use the portions of marbles to discuss rounding of decimal numbers.

46½ red (or 46) – {oxygen-46.4%}
4 ¼ white (or 4) – {calcium-4.2%}
2 yellow {potassium-2%}
2 ½ clear (or 2) – {sodium-2.4%}
2 ½ blue (or 3) - {magnesium-2.3%}
8¼ silver (or 8) – {aluminum-8.2%}
28 ¼ green (or 28) – {silicon-28.2%}
5 ¾ black (or 6) – {iron-5.6%}
1 marble or a piece of a marble of another color to represent all other minor elements)

Cards for each of the elements
A copy of the Periodic Table of the Elements
Task Cards for Follow-up Work

Lesson Plan

(Note: Italicized words give appropriate language for the presentation as a suggestion.)

1. **Hold up the chart of the earth's layers and review the names of the layers**: ***inner core, outer core, lower mantle, upper mantle, crust/lithosphere, hydrosphere, atmosphere*** as indicated in your chart.

2. Review the terminology for the ***lithosphere*** vs. ***hydrosphere*. **Equate the term ***lithosphere*** with ***crust***. Make the distinction between the solid lithosphere and liquid hydrosphere.

3. Introduce the concept of the earth being made of only eight elements: *"Did you know that the earth's crust is made of only 8 basic ingredients? The ingredients are called* ***elements.****"*

4. Show Periodic Table of the Elements. *This is called the* ***Periodic Table of the Elements****. It shows all the elements that occur in and around our planet. There are 117 elements on the chart. 92 of these elements occur naturally in the air, the water or the crust.* **NOTE: Check your chart for the number of elements present. Charts vary.**

   But even though there are 92 natural elements, only 8 elements make up most of the earth's crust.

5. Show the container of marbles. *There are 100 marbles in this container. They represent the elements in the earth's crust. Do you see that there are different colors of marbles? The different colors represent the different elements that make up the earth's crust.*

6. Have the students separate the marbles into the different colors. *What do you notice about the numbers of marbles? (Some colors have more marbles than others.)*

   This represents the different amounts of the various elements. The red marbles represent the element ***Oxygen****. Oxygen makes up nearly half of the earth's crust.*

7. Show the Oxygen card. (in red, to match) Discuss the number of marbles out of 100. (46¼ or 47) Compare this to the percentage written on the card.

   What color has the most marbles after the red oxygen marbles? (The green marbles. There are 28 or 28 and a little piece.)

   The green marbles represent the element ***Silicon****. Silicon makes up more than ¼ of the crust.*

8. Show the Silicon card (in green, to match) Again, discuss the number of marbles out of 100 (28 ¼ or 28) and compare to the percentage on the card.

9. Continue through the remaining colors, connecting them with the name of the element and investigating the percentages.
   Let's see if you can match the other marbles with their name cards.
   NOTE: Students should be able to match these, if only by color. Check by counting and comparing the percentages.

10. Once the materials are matched, show the blank circle graph. (or give a blank graph to each student)
    *This is a **circle graph.** Circle graphs are good for comparing quantities that make up a whole. Since our marbles represent all the elements that make up the earth's crust, we can use a circle graph to make a picture that compares the various quantities.*

    Which section do you think represents Oxygen? (the largest section) This section can be colored red to match the red marbles that represent Oxygen.

11. Point out the Key in the bottom corner of the graph page. Review the parts of the Key and its purpose as follows:
    Do you see the box in the bottom corner of the page? It is called a Key. It defines the meaning of the different colors we are using to represent the different elements. Color in the box next to the word "Oxygen" the same color as the part of the graph that represents Oxygen. (red)

12. Point to the next largest section. (This represents silicon so should be colored green.) Continue to support the students to match the sections and color in both the graph and the key.
    Do you think you could match the sections of the graph to the different quantities?
    What color do you think this section should be?

NOTE: You could move away from the students as they finish this work independently. Before you move away, help the students brainstorm an appropriate title for the graph and introduce the follow-up task cards.

The Forces of Weather

Direct Aims:

- To help students understand that weather takes place in the air
- To help students differentiate between weather and weathering

Indirect Aims:

- To help students differentiate between weather and climate

Materials:

- Picture cards of the different types of weather

Lesson: (Note: Italicized words are suggestions for language to use during the lesson.)

Reflect on the weather outside on the day you give the lesson.

When it rains of snows or the sun is shining, we call what is happening around us, the weather. Weather takes place in the atmosphere, the blanket of air that surrounds the earth.

Let's look at these pictures and talk about the kinds of weather they represent. (precipitation in rain or snow, temperature of cold and hot, wind)

There are also extreme weather examples of these. Extreme wind is called a tornado or a hurricane.

The weather affects us in many ways. We have to know what to wear. Sometimes we have to seek shelter from the weather.

In our next lesson, we'll look at how the weather affects the surface of the earth.

Weathering

Direct Aims:

To understand the various types of weather
To understand how these weather conditions affects the land surface

Indirect Aims:

To prepare for the study of sedimentary rock

Materials:

Photos of different types of weather

Lesson: (Note: Italicized words are suggestions for language to use during the lesson.)

We all are affected by the weather. We base what we wear on the temperature and conditions outside. But did you ever think about how the weather affects the surface of our earth?

There are lots of different weather conditions: Rain, Wind, Sunshine, Clouds, Large temperature changes. They all take place in the air that surrounds the earth.

When we talk about how these conditions affect the earth's surface, we call it ***weathering.***

Any type of weather can cause the surface of the earth to be worn away. Rain, even gentle rain, can have a strong impact on the earth's surface on which it falls. **Show picture of the Storm near Elko, NV. Discuss how the rain may affect the ground.**

When rivers flood, there can be a huge impact on the surrounding land surfaces. **Show picture of the flooded river and discuss how the moving water may be affecting the ground that normally holds the river.**

Wind can literally blow the earth's surface into tiny particles and blow them away. **Show picture of the wind storm and discuss how the housing project might look after the dust-laden wind passes by.**

Extreme cold temperature helps with weathering because the moisture inside the rock freezes and expands. This weakens the bonds that hold the rock together and causes it to break into pieces. If the cold temperatures also bring snow, the water is frozen all around the rock. This will eventually break the rock into smaller and smaller pieces. This happens in and around glaciers. **Show picture of the glacier and discuss the various sizes of rock that have been formed. Note the caption.**

In places where the sun shines brightly, the rock can heat up to temperatures that make them too hot to touch. Rocks and most other things expand when they are hot. Then, when the air cools at night, the rocks shrink or contract. The expansion and contraction over time can cause the rocks to crack and break apart.

All of these weathering effects have an important role to play on the formation of rocks. How do you think the weather affects rocks and the formation of rocks?

Grains of Sand

Direct Aims:

To define "grain" in rocks
To note the variations that can exist in size, color, shape and texture
To relate the grains of sand to the rocks that made them

Indirect Aims:

Organization
Classification
Use of appropriate descriptive terms for minerals

Materials:

Course grained sand (derived from granite)
Samples of different colored granite
Samples of components of granite: various quartz, feldspar, mica
Toothpicks for separating grains from one another
Magnifying glasses
Labsheet

Lesson: (Note: Italicized words are suggestions for language to use during the lesson.)

Have you ever looked at sand? I mean really looked at each tiny grain and examined how it looked? Wondered what kind of rock it came from?

Do all the grains look exactly the same? Let's take a look.

Have the children work in small groups to begin to examine the grains with their naked eyes.
Write their observations on a chart paper or dry erase board.
Then hand the students magnifying glasses and see how their observations change.
With granite-based sand, there should be distinctly different types of grains:
Chunky and flat; translucent and opaque; shiny and dull; various colors.

You've seen lots of differences among the grains. Let's see if there are any that seem to go together and list them in a chart. (The qualities will vary greatly, but this sample will guide you:)

Flat and Shiny: Gray	Chunky and Translucent: Milky color	Chunky and Opaque: White
Flat and Shiny: White	Chunky and Translucent: Clear	Chunky and Opaque: Black

What sort of rock could have made this sand?

Show the samples of granite in various colors.

This is granite. Do the grains in the sand look like they could have come from this?

When we look at rocks, we look at the ***grains*** *and describe their size, shape, and texture, even when they are part of a solid rock.*

Show component minerals such as feldspar, mica and quartz

These rocks are actually minerals that make up the granite. We describe them using the kinds of words we used to describe the grains: flat, chunky or massive, gray, shiny, translucent, opaque, etc. When we study minerals, these are the sorts of words we'll use.

Section 3: Plate Tectonics
(Students Ages 6 through 12+)

We live on the outer layer of the earth known as the lithosphere or crust. The lithosphere floats on the asthenosphere or top layer of the mantle. The lithosphere is brittle and relatively light weight compared to the inner parts of the earth. The lithosphere has broken into sections called plates. Earthquakes occur in the lithosphere layer of the earth.

The aesthenosphere is partially molten so it is neither completely solid nor completely liquid. It is "plastic" which means it can bend and fold. The movement of the plates on top of the aesthenosphere causes earthquakes, volcanoes, and cracks or rifts in the lithosphere and formation of new crust.

In order to understand how different types of rock form, it is important for students to have the concept of the changing nature of the earth's surface. With each plate movement, rocks are put under pressure and often drive to depths that add heat to equation. This is the work that results in igneous and metamorphic rock. With weather conditions, rock is constantly eroded away. This is the work that results in sedimentary rock.

The activities in this section are designed to help students form concepts of layers, movements of the plates, and the consequence of plate movements in the past and present. They are by no means exhaustive, but can give the teacher a number of ways to demonstrate important earth science concepts.

As in previous sections, the lessons follow a typical Montessori-style presentation with notes to the teacher to guide the direct aims of the lesson while remaining aware of the indirect aims that are underlying the work. Some of these lessons include explanations for the teacher who may be less comfortable with earth science concepts.

There are also statements at the end of many of the lessons, especially after a demonstration or procedure from which the students may internalize a science concept. These statements may be made into cards that can be copied into science notebooks along with notes from the lessons or observations from the activity. In many Montessori classrooms, the statement cards are kept with shelf work and can be used for illustrations, summaries, or even handwriting practice that connects to the science work.

Plate Tectonics

Lesson/Demonstration #1: The Crust is made of Plates

Direct Aims:
- Present the concept of tectonic plates and plate movement
- To define different characteristics of the layers
- To identify the different tectonic plates using a map

Indirect aims:
- Review the outer layers of the earth
- Preparation for further work in tectonics (convergence, divergence, etc. and the resulting landforms.

Materials:
- A plate or a few small plates
- A baking dish or jelly roll pan filled with Jello
- A geographic or geologic map of the earth with various continental and smaller plates' outlines marked

Procedure:
- Discuss the theory of plate tectonics. Tectonics explains the ever-changing surface of the earth. The movement of the plates is the reason geologic events occur: volcanoes, mountain formation, earthquakes, etc.
- The two basic premises that support the theory of plate tectonics are
    1. The lithosphere, or outer layer of the earth, is broken into pieces called plates.
    2. The plates are constantly moving slowly as they float on the semi-molten asthenosphere, the top layer of the mantle.

2. Discuss the lithosphere: The lithosphere is the surface of the earth. It is made of rocks and minerals. The lithosphere is brittle and breaks easily.
3. Hold up one of the plates. Ask the students to describe the characteristics of the plate, with a focus on the broad, wide surface area (for holding food) and the relatively thin 3rd dimension: the thickness.
4. Place the plates on the jello. Move the plates around a bit and observe what happens.
5. Ask the students to make some hypotheses about how this model reflects what happens on the surface of the earth.
6. Look at the map and notice the various plates. If labeled, discuss the names of the plates.

Observation:

Explanation for the teacher/science behind the work: We live on the outer layer of the earth known as the lithosphere or crust. The lithosphere floats on the asthenosphere or top layer of the mantle. The lithosphere is brittle and relatively light weight compared to the inner parts of the earth. The lithosphere has broken into sections called plates. Earthquakes occur in the lithosphere layer of the earth.

The asthenosphere is partially molten so it is neither completely solid nor completely liquid. It is "plastic" which means it can bend and fold. The movement of the plates on top of the asthenosphere causes earthquakes, volcanoes, and cracks or rifts in the lithosphere and formation of new crust.

Statement: The lithosphere or crust of the earth is broken into large pieces called plates that move slowly around on the surface of the earth, sometimes crashing into each other, sometimes moving away from each other.

Plate Tectonics

Lesson/Demonstration #2: Brittle vs. Plastic

Direct aims:
- To experience and label the qualities of brittle and plastic
- To compare the experience of brittle and plastic objects to the earth's crust

Indirect Aims:
- To review the concept of layers of the earth's crust
- To imagine the forces that shaped our planet

Materials:
- Scraps of broken ceramic dishes or rocks
- Silly Putty
- A hammer
- A towel
- Goggles

Procedure:

7. Pull gently on a rock or piece of ceramic. Describe what happens.
8. Wrap the rock or piece of ceramic in a towel. Using the hammer, hit it with varying degrees of force. Open the towel and observe what happened.
9. Pull gently on the Silly Putty.
10. Describe the difference between amounts of force and how the substances reacted to the forces.
11. Pull quickly and forcefully on the Silly Putty. Describe what happens.

Observation: The hard rock or ceramic broke under force. The Silly Putty stretched when pulled gently and broke when pulled forcefully.

The rock is called brittle because it breaks under force. The Silly Putty is pliable or plastic under gentle force and brittle under strong force.

Explanation for the teacher/science behind the work: This demonstration helps the students learn the vocabulary of brittle and plastic and relate the terms to the different layers of the earth.

Statement: The lithosphere or crust of the earth is brittle. The asthenosphere is plastic so it can bend and fold.

Plate Tectonics

Lesson/Demonstration #3a: Plates Move on the Earth

Direct aims:

- Work with a model of the crust and its plates
- To begin to form the concept of tectonic plates moving on the earth

Indirect Aims:

- To imagine the forces shaping our planet
- To inspire thought about continent placement

Materials:

- Hardboiled Egg with shell for each student or pairs of students

Procedure:

1. Gently tap on the egg to crack the shell.
2. Gently push on the shell until it moves in various directions.
3. Observe what happens to the shell as you exert force on it.

Observation: The brittle egg shell cracks and breaks as it moves across the surface of the inner egg. Sometimes the shell buckles and pushes up (like mountain building) sometimes pieces move under other pieces (like subduction) and sometimes the pieces fall away (like rock slides).

Explanation for the teacher/science behind the work: This demonstration helps the students imagine the results of plate movement.

Statement: The crust of the earth is broken into "plates" that move around on the mantle.

Plate Tectonics

Lesson/Demonstration #3b: What Happens at the Edges?

Direct aims:
- Work with a model of the crust and its plates
- To observe that most of the “action” takes place at the edges of the plates
- To experience what happens at the edges between two plates that are colliding or slipping by or moving away from one another

Indirect Aims:
- To imagine the forces shaping our planet
- To inspire thought about the edges of the tectonic plates and begin to think about the result of the collisions.

Materials:
- Hardboiled Egg with shell for each student or pairs of students
- Marker
- Dull or serrated knife

Procedure:
1. Draw a circle around the narrow end of the egg.
2. Use the knife to gently make a crack along the line.
3. Carefully twist and move the circular “plate” and observe what happens along the edges.

Observation: The edges of the egg shell “plates” crack and break as they move against each other and the inner egg “mantle.” Sometimes the shell buckles and pushes up (like convergent boundaries and mountain building), sometimes pieces move under other pieces (like convergent boundaries and subduction), sometimes the “plates” pull away from each other (like divergent boundaries) and sometimes the pieces rub against each other and cause bits of shell to fall away (like transform boundaries and rock slides). With just two “plates” (as compared to the many cracks from the previous demonstration), there is even greater imitation of what actually happens on the earth.

Explanation for the teacher/science behind the work: Because this demonstration shows two distinct “plates,” students can see how most of the action occurs at the edges, imitating nature.

Statement: Plates can move toward each other (convergent boundary), away from each other (divergent boundary) or slip alongside each other (transform boundary).

Plate Tectonics

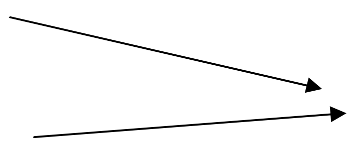
Lesson/Demonstration #4a: Convergent and Divergent Movement

Direct aims:
- Work with a model of the crust and its plates
- To observe that most of the "action" takes place at the edges of the plates
- To experience what happens at the edges between two plates that are colliding or slipping by or moving away from one another

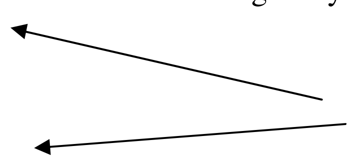
Indirect Aims:
- To imagine the forces shaping our planet
- To inspire thought about the edges of the tectonic plates and begin to think about the result of the collisions

Materials:
1. Montessori Geometry Box of Sticks (or Cut-out Arrows; see "Materials" section)
2. Two tectonic plate sections (see "Materials" section)
3. Geographic Map that shows plate boundaries

Procedure:
(Montessori elementary teachers may begin with convergent/divergent lines lesson.)
1. Lay out two arrows in the following manner:



2. Discuss how these arrows would eventually meet or converge if they kept going.
3. Convergent means "to come together"
4. Repeat with the arrows moving away from each other: divergent



5. Show African and South American Plate models.
6. Place arrows on the plates to show the direction they are moving. (These plates are diverging.)
7. Discuss divergent boundary: when the plates are moving apart.
8. Add the Nazca Plate model and the arrow that shows the direction it is moving (Converging with South American plate)
9. Discuss convergent boundary: when the plates are moving together
10. Look at the map identifying convergent and divergent boundaries (usually noted in different colors.)
11. Students may lay arrows on the various plates to demonstrate the direction the plate is moving.

Observation: Students may observe that the plates are generally moving in an east to west direction, which makes one edge of the plate diverge from the plate on the east, while converging with the plate on the west.

Explanation for the teacher/science behind the work: Because this demo shows two distinct "plates," students can see how most of the action occurs at the edges, which imitates nature.

Statement: Geologists use the terms "convergent" and "divergent" to describe the direction of movement of the tectonic plates either toward or away from each other.

Follow-up: Provide small arrows and photo putty to label the direction of the plates on a globe.

Plate Tectonics

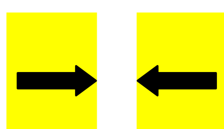
Lesson/Demonstration #4b: Plate Movement

Direct aims:
- Work with a model of the crust and its plates
- To observe that most of the "action" takes place at the edges of the plates
- To experience what happens at the edges between two plates that are colliding or slipping by or moving away from one another

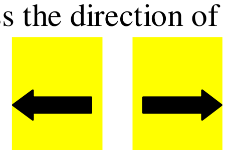
Indirect Aims:
- To imagine the forces shaping our planet
- To inspire thought about the edges of the tectonic plates and begin to think about the result of the collisions

Materials:
1. 2 telephone books for each pair of students
2. Marbles

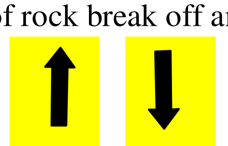
Procedure:
1. **Convergent Movement**
    - Lay the phone books on a table with the bound sides facing each other.
    - Discuss that the phone books are a model of the plates on the earth.
    - Slide the phone books toward each other until they touch.
    - Discuss the direction of the movement. This demonstrates plate convergence.



2. **Divergent Movement**
    - Move the phone books away from each other.
    - Discuss the direction of the movement. This demonstrates plate divergence.



3. **Lateral Movement**
    - Put the bound edges of the phone books together.
    - Move the books in opposite directions.
    - Discuss the direction of the movement. This demonstrates conservative movement that occurs at transform boundaries.
    - Place a few marbles between the bound edges and repeat the movement.
    - The marbles rolling around demonstrate what happens at transform boundaries: bits of rock break off and slip around in an earthquake.



4. **Mountain building**
    - Place the phone books an inch apart with the open edges facing each other.
    - Slowly move the books toward each other (convergence).
    - Note what happens to the pages: some rise up, some fold, others form layers in between, while others go underneath.
    - Discussion: This is what happens at convergent boundaries. Earthquakes occur and when layers are pushed up, mountains are formed.
    - Looking at a map, find places where mountain ranges have formed by convergent plate movement (Cascades, Appalachians; USA; Himalayas: Asia; Alps: Europe)

Observation: Landforms, such as mountain ranges and trenches, are often the result of what is happening at the edges of moving earth plates.

Explanation for the teacher/science behind the work:

Statement: Landforms, such as mountain ranges and trenches, are often the result of what is happening at the edges of moving earth plates.

Follow-up: Provide small arrows, landform labels and photo putty to label mountain ranges, rift valleys and oceanic trenches that occur as the result of plate movement.

Plate Tectonics

Lesson/ Demonstration: Convergent Plates: Mountain Building and Subduction

Direct Aims:
- To understand what happens when tectonic plates converge
- To observe landforms that have occurred from convergence

Materials:
- For Telephone Book Demonstration: Two phone books for each pair of students
- For Cookie Subduction Model: Enough sandwich-style cookies to have one for each student

Lesson: (Note: Italicized words are suggestions for language to use during the lesson.)

When the plates of the earth's surface collide two things can happen:

1. *The layers push against each other. Folds occur or mountains rise up.*

   Demonstration: Telephone Book Mountains
   a. *Place two phone books on a table with pages facing*
   b. *Push the phone books together (convergence)*
   c. *Observe what happens to the pages.*
   d. *Compare this to mountain building at convergent boundaries.*

2. *One layer, the heavier of the two, goes under the other. This is called subduction. The layer that goes under gets very hot because it is closer to the hot center of the earth. Pockets of magma may get pushed up and the hot magma can have an effect on the rocks that are going under the top layer.*

   Demonstration: Cookie Subduction Model
   (Note: this could be done in a separate lesson about subduction.)
   a. *Take apart a sandwich-style cookie with a cream center.*
   b. *Using the half that has the cream on top, put the cookie just under your two front teeth. Your front teeth represent one tectonic plate and the cookie represents the other.*
   c. *Slowly push the cookie toward the inside of your mouth, while the cream filling is jammed up against your front teeth.*
   d. *Have a friend tell you what is happening to the filling.* (It is folding up against your teeth while the cookie is being subducted below.

Explanation for the Teacher/Science behind the work:

When two plates crash together it is called a convergent boundary. Because plates only move a few centimeters each year, collisions are slow and last for millions of years.

Oceanic plates tend to be heavier than continental plates. Therefore, when an oceanic plate converges with a continental plate, the oceanic plate tends to be forced under the continental plate, or subducted under the continental plate. When a plate is subducted, a trench occurs as one plate dives below another. The rock in this plate melts as it approaches the depths of the mantle. Earthquakes occur. Volcanoes form to release the molten rock to the surface.

Statement: When plates converge, mountains and trenches form. Earthquakes occur in these areas as the plates move together. Subducted plates melt and the molten rock is released to the surface through volcanoes.

Plate Tectonics

Lesson/Demonstration #4d: Divergent Boundaries

Direct Aims:

- To understand what happens when tectonic plates move apart

Indirect Aims:

- To prepare for further study of plate movement and the resulting landforms

Materials:

1. 2 phone books
2. Balloon
3. A shoe box with a lid
4. Two small rolls of paper or paper towel cut to fit inside the box
5. Markers / crayons

Lesson:

1. **Valleys and Ridges #1**
   - Put an under-inflated balloon under the phone books (represents magma)
   - Place the phone books next to each other again and gently pull them apart.
   - **Observation:** The plate layers bend slightly as they move away from each other. This imitates what happens on the earth.
   - **Discussion:** What would happen with the magma when the plates pull apart? Magma would rise up into the space and form new crust / lithosphere as it cooled.
   - Looking at a map, find places where the plates are divergent and the land forms present. In oceans, this is called a mid-ocean ridge (Atlantic Ocean) and on land it is called a rift valley. (Iceland)

2. **Valleys and Ridges #2**
   - Have the students cut a narrow slit in the center of the lid of the shoe box (long enough and thick enough for two pieces of paper or paper towel to slip through at the same time)
   - Draw a picture on the end of the first two paper towels showing an ocean environment
   - Pull the towels up through the slit and away from each other.
   - **Observation:** the paper towels bend upward as they are pushed up from underneath. This mimics the ridge that forms on each side of a divergent boundary.
   - **Discussion:** How does this model demonstrate what happens with divergent plates under the ocean?

Explanation for the teacher/science behind the work: When tectonic plates move away from each other they form divergent boundaries. The crack is formed on parallel fault lines. As the plates move away, the land between the fault lines sinks into the aesthenosphere resulting in two clear ridges. Between the ridges, molten rock rises to the surface, forming new land in a rift valley.

Statement: When plates move away from each other, molten material rises to the surface and new land is formed.

Follow-up: Provide small arrows, landform labels and photo putty to label mid-ocean ridges and rift valleys (ex. Mid-Atlantic Ridge and East Pacific Ridge) and rift valleys on the land (ex. East Africa Rift in Kenya and Ethiopia; Rio Grande Rift in New Mexico)

Plate Tectonics

Lesson/Demonstration #5a: Transform Boundaries

Direct aims:

- To understand what happens to the land at transform boundaries
- To understand how plates move side by side as well as away from and toward one another

Indirect Aims:

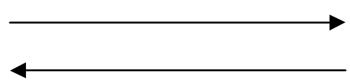
- Preparation for understanding different types of transform faults

Materials:

1. Montessori Geometry Box of Sticks (or Cut-out Arrows; see "Materials" section)
2. Antarctic Plate Model
3. Geographic Map that shows plate boundaries

Procedure:

4. Review Convergent and Divergent
5. Lay out two arrows in the following manner:



6. Discuss how the lines are parallel, but they indicate movement in opposite directions.
7. Show Antarctic Plate Model.
8. Look at the Scotia Plate. It lies between the South American Plate and the Antarctic plate.
9. The north and south edges of the Scotia plate represent transform boundaries, places where the plates are moving in opposite directions alongside each other. It is as if the Scotia plate is stuck between the two major plates and can simply sit still and grind against the other two plates as they move.
10. Have students put one hand on top of the other and move them in opposite directions. They can feel the heat caused by friction when they move their hands back and forth.
11. In transform boundaries, the plates grind against each other. Earthquakes are common at transform boundaries.
12. A transform boundary creates a transform fault.
13. Show the students the location of the San Andreas Fault in California. This is a transform Boundary / Fault between the North American Plate and the Pacific Plate.
14. Students may lay arrows on a globe to demonstrate the direction the plates are moving.

Observation:

Explanation for the teacher/science behind the work: The transform boundaries occur between plates that are sliding by each other in opposite directions. Transform Faults occur at these locations and there are frequent earthquakes.

Statement: Transform Boundaries are boundaries between plates that are slipping side by side.

Plate Tectonics

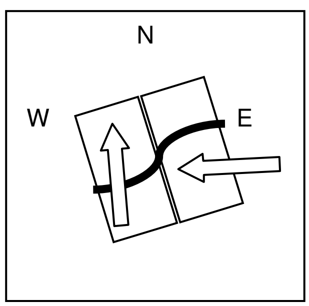
Lesson/Demonstration #5b: Transform Boundaries demonstration

Direct aims:
- To understand what happens to the land at transform boundaries
- To understand how plates move side by side as well as away from and toward one another

Indirect Aims:
- Preparation for understanding different types of transform faults

Materials:
1. Two layered-wafer cookies for each pair of students
2. Piece of paper, large than the wafers, labeled N,S,E,W for the cardinal directions
3. Tube of frosting
4. Geographic Map that shows plate boundaries

Procedure:
5. Review Lesson 5 in which you defined transform boundaries
6. Lay the cookies side-by-side on the paper in a northwesterly direction. (Cookies represent the Pacific Plate and the North American Plate)
7. Spread a line of frosting across the two cookies. (To represent a road)



8. Move the cookie on the left in a northwesterly direction, while moving the cookie on the right in a westerly direction.
9. **Observe:** Do the plates move or stick? Is there sideways motion? What happens along the edges of the plates? What happens to the road?
10. Show the students the location of the San Andreas Fault in California. This is a transform Boundary / Fault between the North American Plate and the Pacific Plate.
11. Students may lay arrows on a globe to demonstrate the direction the plates are moving.

Explanation for the teacher/science behind the work: The transform boundaries occur between plates that are sliding by each other in opposite directions. Transform Faults occur at these locations and there are frequent earthquakes.

Statement: Transform Boundaries are boundaries between plates that are slipping side by side.

Plate Tectonics

Lesson/Demonstration #6: The Ring of Fire

Direct Aims:
- To understand what happens at the edges of tectonic plates

Indirect Aims:
- To prepare for further study of volcanoes and igneous rocks

Materials:
- Map of tectonic plates
- Copies for students
- Red markers
- Labels for volcano identification

Lesson:

We have looked at the various types of boundaries that occur at the edges of plates.

There are convergent boundaries where the plates move together. When this occurs one plate folds and builds mountains while the other pushes underneath. When this occurs, magma builds up near the surface and volcanoes are created to release the magma.

There are divergent boundaries where the plates move apart. When this occurs, magma wells up between the ridges and volcanoes occur in the rift valleys.

Look at this map of the tectonic plates that cover our planet. The Pacific Plate is located between North America and Asia. The arrows show us the direction the plates are moving in relationship with one another.

Can you see the convergent boundaries? Where are they? (Mostly on the western side of the Pacific Plate between the Pacific Plate and the Eurasian Plate, the North American plate at Alaska and the Indo-Australian Plate and between the Nazca Plate and the South American plate) *What might be happening at these convergent boundaries?* (Volcanoes)

All along the convergent boundaries are hundreds of volcanoes. They form a ring that stretches from the tip of South America up along the coast of North America, across the top of the Pacific Plate at Alaska, down along the Eurasian Plate and the Indo-Australian Plate. There are many volcanoes along this convergent boundary, so it has been called The Ring of Fire. There are many earthquakes along this ring as well.

Have the students draw the Ring of Fire on their maps.
Next, have them add names of significant volcanoes that occur all around the ring.

Explanation for the teacher/science behind the work: As the converging plates collide, the oceanic plate is subducted below the continental plate resulting in off-shore trenches and mountain building volcanoes on the continental shores. Frequent earthquakes and eruptions occur along this ring, giving it the name, the Ring of Fire.

Statement: The Ring of Fire is formed at convergent boundaries around the Pacific Plate and the Nazca Plate and the surrounding continental plates of North America, South America, Eurasia and Indo-Australia Plates.

Follow-up

1. Look up current volcanic activity on one of the following websites: http://www.volcano.si.edu/reports/usgs/ or http://volcanoes.usgs.gov/

2. Look up current earthquake activity on one of these: http://earthquake.usgs.gov/ or http://www.iris.edu/seismon/

Plate Tectonics

Lesson/Demonstration #7: Volcano

Direct Aims:

- To understand how volcanoes are formed
- To relate the formation of volcanoes to locations of plate boundaries
- To learn about hot spots and volcanoes that form over them
- To learn the parts of the volcano

Indirect Aims:

- To prepare for learning about igneous rock types related to formation through volcanoes

Materials:

- Chart of plate boundaries
- Chart of volcano parts
- Photographs of various types of volcanoes

Lesson: (Note: Italicized words are suggestions for language to use during the lesson.)

*When we studied convergent plate boundaries, we saw that subducting plates melted into **magma** that rises to the surface. Magma is a mixture of substances that form rocks, gases, and water. The magma comes up through weak spots in the earth's crust. These spots are called **volcanoes.** When magma reaches the surface of the earth it is called **lava.** As lava flows down the volcano, it builds up the surface of the earth.*

While volcanoes usually occur at convergent boundaries, magma is also released at divergent boundaries. Rift Valleys in the ocean floor and on land form volcanoes and build new land between the ridges.

*Sometimes volcanoes form over **hot spots** in the mantle. Substances in the earth's mantle rise then melt and form magma. When the magma breaks through the crust coming to the surface, a volcano is formed over the hot spot. Hot spots can occur in the center of a plate far from the plate boundary. As the plate moves over the hot spot a series of volcanoes form. The Hawaiian Islands formed over millions of years as the Pacific Plate passed over a hot spot.*

*Under all volcanoes lies a **magma chamber**. The molten magma rises to the surface through a main **conduit vent** or **side vents**. Once it reaches the surface, the magma flowing out is called **lava.** Lava flows form the sides of the volcano.*

*There are several different types of volcanoes based on the way they were formed. If the magma flows very slowly it may build up pressure and explode, producing ash and cinders. These cinders gradually build up a **cinder cone volcano** with steep sides. A **composite volcano** is formed when layers of flowing lava alternating with layers of explosive ash and cinders create the sides. Composite volcanoes are also cone-shaped. **Shield volcanoes** build gradually with slow-flowing lava. These volcanoes have wide, gently-sloping sides.*

Section 4: Rocks and Minerals
(Students Ages 6 through 12+)

The section focuses on the various types of rocks and minerals, how they are formed, how they are classified, their characteristics and how they change. It is natural to follow the work on Plate Tectonics with this study, because rocks and minerals are a direct result of the tectonic action. However, these lessons and activities can also comfortably stand on their own.

Children's natural interest in rocks makes even the simplest matching work a sought-after activity. These activities are excellent preparation for the more formal lessons. A child who has spent time with matching and organizing will take those experiences into the formal lessons, making connections between what they have observed and the information that is being presented.

Getting Familiar with Rocks and Minerals

Matching Exercises

- **Numbered to Un-numbered**
  1. Using numbered specimens, match the unnumbered specimens by comparing color, grain, texture and overall appearance.
  2. Begin with 3 at a time for younger children, but you could do up to 6 at a time for older children.
  3. Begin working within a single group (igneous, sedimentary, metamorphic, minerals) before combining different groups, with the indirect aim of becoming familiar with the groups
  4. Name the specimens for the children as you introduce the activity, but do not make the names the focal point.

- **Numbered set to labels**
  1. Use the numbered set of specimens, matching them to name labels.
  2. Make a set of name labels that have the corresponding number on the back so the child can correct herself.

- **Un-numbered set to the names (no control)**

- **Numbered specimens to Definition Cards (with control)**
  1. Read the definition cards.
  2. Match to the specimens by definition, but using the numbered specimens for a control of error.

- **Un-numbered specimens to Definition Cards (no control of error)**
  1. This is like the exercise above, but without the control of error.
  2. Hve the numbered specimens available for self-correction.

- **Who Am I? Games**
  1. Children make up clues of their own to quiz one another and match to the specimens, using their knowledge from the definition cards..
  2. Children read the “Who am I? cards that come with the specimens and match with control and without.

Getting Familiar with Rocks and Minerals

Classifying Exercises

- **Grading**
  1. Using one type of rock (sedimentary, igneous or metamorphic) or a group of minerals, grade them according to one particular characteristic.
  2. Example characteristics to use:
     A. Grain size: smallest grain to the largest grain
     B. Texture: smoothest to roughest
     C. Dark to light color

- **Sort by color**
  1. Works especially well with minerals, but can also be done with the other types of rocks mixed up (i.e. a few sedimentary, metamorphic and igneous all at once.)
  2. Choose only a few at a time.
  3. This requires more discernment as there are many subtle differences and variations.
  4. Because there is no right or wrong answer, this is a great exercise in observation and decision-making.

- **Sort into groups of rock type: igneous, metamorphic, sedimentary**
  1. Initially this could be done by the labeled rocks: I for igneous, S for sedimentary, etc.
  2. As the student becomes more familiar with the particular varieties, they can use the unlabeled specimens.

- **Sort minerals into groups with similar mineral characteristic such as harness, crystal form, etc**.
  1. This is a fairly advanced type of classification, but one that will definitely

Rocks

Lesson/Demonstration #1: Types of Rock

Direct Aims:
- To become familiar with the names of the different types of rock
- To learn how each type of rock is formed
- To examine the qualities of each type of rock

Indirect Aims:
- Preparation for the study of the rock cycle

Materials:
- Colored paper circles from the rock cycle with names of the various types of rock
- Rock samples of each type (igneous, sedimentary, metamorphic)

Lesson (Note: Italicized words are suggestions for language to use during the lesson.)

1. Lay out the Red Igneous Rock Circle.
   A. *Igneous Rocks are formed from the molten rock in the mantle layer of the earth.*
   B. *Igneous Rocks can form close to the surface of the earth as in a volcano or deep below the surface in pockets.*

2. Lay out the Lava.
   A. *This is Lava. It was molten rock that cooled quickly on or near the surface of the earth. It came from a volcano.*
   B. Lay out the illustration of a volcano.

3. Lay out the Granite.
   A. *This is granite. It was molten rock that cooled deep below the surface of the earth. It cooled slowly, forming different types of crystals as it cooled.*
   B. Lay out the illustration of the underground pocket of molten rock.

      i. (Side bar for the teacher) **Extrusive** igneous rocks cool on or near the surface of the earth. Sometimes extrusive igneous rock is called **volcanic.** They come from vents in a volcano and tend to cool quickly. Lava is an example of this type of igneous rock.
      ii. (Side bar for the teacher) **Intrusive** igneous rocks cool deep below the surface of the earth. Sometimes intrusive igneous rock is called **plutonic.** They come from pockets of molten rock that cooled as they moved toward the cooler upper layers of the mantle. Granite is an example of this type of igneous rock.

4. Lay out the Brown Sedimentary Rock Circle
   A. *Sedimentary Rocks are made of small bits and pieces, or sediments, of other materials.*
   B. *The materials could be pieces of shell or ground up rock, anything that can be crushed or weathered to make tiny bits.*

   C. *The tiny particles fall to the ground and layer after layer are laid down on top of another. Eventually the weight of all the layers causes the tiny particles to harden into a solid rock.*

5. Lay out the sandstone.
   A. *This is sandstone.*
   B. *It is made of tiny sand particles that come from rock that has been broken down by either wind, rain, freezing, thawing, or running water: anything that weathers the rock.*

6. Lay out the limestone.
   A. *This is limestone.*
   B. *It is made of the broken shells of sea animals.*

7. Lay out the shale.
   A. *This is shale.*
   B. *It is made of layers of mud like lies at the edge or bottom of a shallow lake or inland sea.*

8. Lay out the gray Metamorphic Rock Circle.
   A. *Metamorphic Rock is rock that has changed form due to pressure and heat.*
   B. *Metamorphic rock could have started its life as either igneous rock or sedimentary rock.*

9. Lay out the Marble.
   A. *This is Marble.*
   B. *One of the parent rocks that can become marble is limestone*.

10. Lay out the Quartzite.
    A. *This is Quartzite.*
    B. *Quartzite is metamorphosed sandstone.*

11. Lay out the Slate.
    A. *This is Slate.*
    B. *The parent rock of slate is shale.*

Follow-up

1. Students match the un-numbered specimens to the numbered by sight, comparing grain size, color, texture and overall appearance.

2. Students sort the numbered specimens into the various types, progressing to using the un-numbered specimens.

3. Students make up “Who am I?” stories for each other using the characteristics of the various types of rocks.

4. Students read the identification cards and/or printed “Who am I?” cards to quiz each other and match the rock to the label or information card.

Rocks

Lesson/Demonstration #2: The Rock Cycle

Direct Aims:
- To learn that rock is recyclable and
- To learn the processes involved in rock recycling
- To work with a model of the cycle to learn the basic elements

Indirect Aims:
- To experience "cycle" as a natural phenomenon
- To deepen the understanding of the forces involved in plate tectonics

Materials:
- Colored paper model of the cycle (with corresponding arrows)
- OPTIONAL: Rock samples of each type (igneous, sedimentary, metamorphic)

Lesson (Note: Italicized words are suggestions for language to use during the lesson.)

1. Lay out the Red Igneous Rock Circle.
   A. *Igneous Rocks are formed from the molten rock in the mantle layer of the earth.*
   B. *Igneous Rocks can form close to the surface of the earth as in a volcano or deep below the surface in pockets.*

2. OPTIONAL: Lay out the various igneous rock specimens from the previous lesson. Review extrusive and intrusive varieties.

3. Lay out the Brown Sedimentary Rock Circle
   A. *Sedimentary Rocks are made of small bits and pieces, or sediments, of other materials.*
   B. *The materials could be pieces of shell or ground up rock, anything that can be crushed or weathered to make tiny bits.*
   C. *The tiny particles fall to the ground and layer after layer are laid down on top of another. Eventually the weight of all the layers causes the tiny particles to harden into a solid rock.*

4. OPTIONAL: Lay out the various sedimentary rock specimens from the previous lesson. Review the various sediments that formed each specimen.

5. Lay out the gray Metamorphic Rock Circle.
   A. *Metamorphic Rock is rock that has changed form due to pressure and heat.*
   B. *Metamorphic rock could have started its life as either igneous rock or sedimentary rock.*

6. OPTIONAL: Lay out the various metamorphic rock specimens from the previous lesson. Review the concept of metamorphism through heat and pressure that formed each specimen.

7. Lay out the red/brown arrow between the igneous and sedimentary circles.
   A. *This arrow reminds us that igneous rock can become sedimentary rock.*

B. Weathering is the name of the process that breaks down the igneous rock.
C. The tiny particles fall or wash to the ground and begin to pile up. (Add the cloud with rain.)
D. With pressure these particles form sedimentary rocks

8. Lay out the gray/brown arrow pointing from the metamorphic circle to the sedimentary circle.
   A. Weathering of exposed metamorphic rock, such as marble, creates sediments.
   B. Metamorphic rock could be weathered mechanically, as with wind.
   C. It could be weathered chemically. As water flows over the rock, it dissolves the rock and the chemical remains flows into the sea where it is "drunk" by sea animals.

9. Lay out the brown/gray arrow pointing from the sedimentary circle to the metamorphic circle.
   A. Sedimentary rock layers get buried deeper and deeper as more layers are piled on top.
   B. The lower layers are under extreme pressure and increasing heat.
   C. The heat and pressure changes the sedimentary rock into a new rock form such as slate, schist or gneiss.

10. Lay out the brown/red arrow pointing from the sedimentary circle to the igneous circle.
    A. Sedimentary rock layers under the ocean sometimes get pushed deep under the edge of a continental plate.
    B. When this happens the heat and pressure cause the sedimentary rock to become molten magma.
    C. The molten magma becomes igneous rock when it cools quickly near the surface or slowly in underground pockets.

11. Lay out the gray/red arrow pointing from the metamorphic circle to the igneous circle.
    A. Metamorphic rock will eventually be buried so deeply that it melts and returns to molten magma form.
    B. The magma will solidify as either volcanic or plutonic igneous rock.

12. Lay out the red/gray arrow pointing from the igneous circle to the metamorphic circle.
    A. Some igneous rock will never reach the surface. As intrusive or plutonic rock solidifies, it may be forced deeper into the ground and once again exposed to heat and pressure.
    B. When this occurs, the granite or other intrusive igneous rock, changes into a new form such as schist or gneiss.

13. Once the chart is complete, note the various cycles with the students:
    A. Igneous to sedimentary to metamorphic back to igneous or
    B. Igneous to metamorphic to sedimentary and back to igneous.

14. Review the title of the chart (the Rock Cycle) and have the students explain why this is the title. Place the title above the chart.

Follow-up

1. Students may repeat the lesson using the chart materials. Be sure to include a key so students can correct their work.

2. Students may draw the rock cycle, including realistic representations of locations where the various rocks are forming, including volcanoes, mountains, rain, subducting plates, etc.

3. Students may research different varieties of rocks that will fit in the various cycles.

Rocks

Lesson/Demonstration #3: Sedimentary Rock (Clastic)

Direct Aims:
- To learn the different types of weathering that can have an affect on rock
- To learn the various materials that form sedimentary rock

Indirect Aims:
- To investigate locations where sedimentary rocks can develop

Materials:
- Some sedimentary rocks
- Rock Cycle Circle for "Sedimentary"
- Egg shells
- Mortar and pestle
- Photographs of different weather conditions

Lesson:

When we looked at the rock cycle, you saw that there were three types of rocks: Igneous, Sedimentary and Metamorphic. Today we're going to investigate how some Sedimentary rocks are formed.

1. Lay out the brown Sedimentary Rock circle.

   Sedimentary rocks are made of sediments. Sediments are tiny, tiny particles that have broken off a large piece of some material. We call the original material the ***parent material.*** *Parent material could be particles of rock or shells from sea animals or decomposed plant material. Sedimentary rocks formed from particles are called* ***clastic sedimentary rocks.***

2. (Note: This part of the lesson could be done as a separate lesson on Weathering, included in the Foundations of Earth Science Section. If done previously, this part of the lesson would be treated as review or left out completely.)
   You might wonder how the parent material got broken down into tiny particles. There are actually several ways, but we can use one big term for it: ***weathering.*** (You can use photographs of weather conditions or symbolic drawings to illustrate as you share each of the types of weathering.)

   Rain
   Wind
   Moving water-a stream or river, waterfalls, wave action
   Freezing and thawing
   Large temperature changes

Any type of weather can cause rock to be worn away. Rain, even gentle rain, will eventually wear down rock and wash it away. Wind can literally blow it into tiny particles and blow them away.

Extreme cold temperature helps with weathering because the moisture inside the rock freezes and expands. This weakens the bonds that hold the rock together and causes it to break into pieces. If the cold temperatures also bring snow, the water is frozen all around the rock. This will eventually break the rock into smaller and smaller pieces.

In places where the sun shines brightly, the rock can heat up to temperatures that make them too hot to touch. Rocks and most other things expand when they are hot. Then, when the air cools at night, the rocks shrink or contract. The expansion and contraction over time can cause the rocks to crack and break apart.

Demonstration:

a. Rub two rocks together to create small particles. This is a simulation of weathering by force. The particles are called **sediments.** When sediments are carried away from the parent material, they are often deposited under water. The weight on the sediments provides the force needed to fuse the sediments together into a solid mass. Rocks formed in this way are called **sedimentary rocks.**

b. Egg shells are made of calcium carbonate. Sea shells are made of the same material, calcium carbonate. Take some egg shell pieces and crush them into tiny particles. These tiny particles are called **sediments.** In the ocean, millions of tiny shelled animals die leaving their shells on the ocean floor. The pressure from the water forces the sediments into solid rock. This is another way sedimentary rocks are formed.

Application:

a. Look at your rock collection. Select all the rocks that appear to be made of tiny particles or grains. You may use a magnifying glass.

b. Can you tell what kinds of grains make up these rocks? (sand, silt, shells, etc.)

c. Rub the surface of the rock with your finger. Do any particles come off? Set aside any specimens that give off particles when rubbed.

d. Compare these specimens with the labeled sedimentary rock specimens from your kit. Can you tell which sedimentary rocks you have been studying? Make a label for your sedimentary rocks. If you found your specimen, make a note of the location where you found your sedimentary rock. (See Rock Specimen Labels in Materials Section)

Ex.:

Sedimentary Rock Specimen
Name: ________________________
Location where found: __________________
Parent material: _______________________

Rocks

Lesson/Demonstration #4: Sedimentary Rock (Chemical)

Direct Aims:

- To work with the process that results in chemical formation of solids (rock salt)
- To understand that some forms of sedimentary rock are the result of chemical precipitation

Indirect Aims:

- To understand the processes that form rocks and minerals

Materials:

- Table salt
- 1 cup of boiling water
- Aluminum pan

Lesson: (Note: Italicized words are suggestions for language to use during the lesson.)

When shallow seas dried up, many of the chemicals that were in the water had no place to go. This demonstration will help you understand how chemical processes form solids. Sometimes these solids are sedimentary rocks, while other times they are minerals.

First we will create a supersaturated solution as might be found in places where sea waters are nearly dried up. Take one cup of boiling water and add table salt, one teaspoon at a time. Stir each teaspoon so it is completely dissolved before you add the next.

Now pour some of the solution on an aluminum plate. Set it in a warm, dark place where it will be undisturbed. Check it again in a day or two.

Observation: Salt Crystals have formed from the evaporated water.

Discussion: Some types of sedimentary rock are formed as water leaches through various types of permeable rock. Limestone is made from water that has precipitated from rock formed of the shells of sea animals. Rock salt is formed from precipitate of sodium chloride.

Follow-up:

1. Examine some chemical sedimentary rocks (chert, halite and gypsum).
2. Identify locations on a map where chemical sedimentary rocks are found and mined.
3. Discuss the history of that land to see how the rock was formed.

Rocks

Lesson/Demonstration #5: Sedimentary Rock: Biogenic

Direct Aims:
- To note the distinction between rock sediments and sediments from living organisms
- To understand that some forms of sedimentary rock are the result of the accumulation of parts of living organisms (plant and animal)

Indirect Aims:
- To understand the processes that form rocks and minerals

Materials:
- Coal
- Limestone
- Dilute hydrochloric acid
- Goggles

Lesson: (Note: Italicized words are suggestions for language to use during the lesson.)

We have studied sedimentary rocks that are formed from small particles. Scientists make a distinction between sedimentary rocks formed from non-living particles and those formed of living particles.

Many sea animals form shells of calcite ($CaCO_3$ *). When these animals die and their shells are deposited on the bottom of the ocean floor, the tiny shell pieces are crushed and forced into rock by the weight of the ocean water. Because these pieces of shell are sediments, the rock they form is a sedimentary rock. But since the sediments are from living organisms, the scientist calls it a* ***biogenetic sedimentary rock.***

*We can test this rock for the presence of shell by placing a couple of drops of dilute hydrochloric acid on the rock. If it fizzes, then there is some sort of shell present. (*Note: Be EXTREMELY careful when using hydrochloric acid. Thoroughly wash the surface of the rock with water after testing.)

There are other biogenetic sedimentary rocks, but the most common of these is ***coal****. Coal is made of sediments of plants.*

Statement Limestone is made from water that has precipitated from rock formed of the shells of sea animals. Coal is formed from sediments of plants

Follow-up:

1. Examine some biogenetic sedimentary rocks (limestone, coal, diatomite, oil shale).
2. Identify locations on a map where biogenic sedimentary rocks are found and mined.
3. Discuss the history of that land to see how the rock was formed.

Rocks

Lesson/Demonstration #6: Igneous Rocks: Definitions and Types

Direct Aims:
- To learn the two types of igneous rocks
- To practice recognizing and classifying types of igneous rocks
- To learn how rocks are formed from molten magma

Indirect Aims:
- To review the layers of the earth, especially the mantle
- To introduce the concept of movement within the magma
- To work with plate tectonics to see how plate movement affects the production of igneous rocks.

Materials:
- Red igneous rock circle (from the Rock Cycle materials)
- Several examples of igneous rocks
- Photographs and charts of volcanoes and magma chambers (from Appendix B)

Lesson: (Note: Italicized words are suggestions for language to use during the lesson.)

When we looked at the rock cycle, you saw that there were three types of rocks: Igneous, Sedimentary and Metamorphic. Today we're going to investigate how Igneous rocks are formed and observe some of the types of igneous rock.

1. Lay out the red Igneous Rock Circle.

Igneous rocks are formed when molten magma cools and solidifies. There are two ways that this can happen. You probably already know something about one way: igneous rocks are formed in volcanoes.

2. Lay out the cross-section of a volcano chart.

*In a volcano, molten magma flows out through vents. When molten magma flows out of the ground it is called **lava.** Lava cools fairly quickly once it reaches the surface. (Lay out a sample of lava.)*

Lava escapes from the volcano in several ways:
Cinder Cones
Vents or dikes
Lava Flows

3. Lay out some extrusive igneous rocks (Basalt, pumice, Phyolite, etc.)

*When igneous rocks are formed outside the volcano, they are called **extrusive igneous rocks.** These rocks cool quickly as they pass out of the volcano through vents or cones. Because of the* *quick cooling the crystals are small or non-existent. Basalt, Pumice, Rhyolite, Porphyry, Obsidian and Scoria are common extrusive igneous rocks.*

4. Lay out some intrusive igneous rocks. (Granite, Diorite, Gabbro, Pegmatite, etc.)

The second way igneous rocks are formed is when molten magma cools in pockets deep below the surface of the earth.

5. Refer to the magma chamber cross-section of a volcano chart.

These rocks are called ***intrusive igneous rock.*** *Intrusive igneous rocks cool slowly, so they have large crystals. Granite, Gabbro, Diorite and Pegmatite are common intrusive igneous rocks.*

Follow-up:

1. Compare different types of extrusive and intrusive igneous rock.
2. Observe variations in grain size using a magnifying glass or microscope if needed. Make hypotheses about why the grain size varies.
3. Make a model of a volcano and an underground magma cavity. Place the different types of igneous rock in relation to where or how it might have been created.

Rocks

Lesson/Demonstration #7: Metamorphic Rocks: Definition and Types

Direct Aims:

- To learn how pressure and heat affect rocks
- To learn characteristics of metamorphic rocks
- To learn the difference between foliated and non-foliated metamorphic rocks.
- To practice recognizing and classifying types of metamorphic rocks

Indirect Aims:

- To review the layers of the earth
- To introduce the concept of change due to conditions below the surface of the earth
- To work with plate tectonics to see how plate movement affects the production of metamorphic rocks.

Materials:

- Gray Metamorphic Rock circle form the Rock cycle materials
- Unbaked prepared cake batter
- Raisins or nuts to sprinkle on top of the cake prior to baking
- Clay: enough for each student or group of students to form three small balls
- Sequins (30 for each student of group of students)
- Length of string for cutting into the balls of clay
- Pieces of wood (2 per student or group of students)
- For **Cookie Subduction Demonstration**: one sandwich-style cookie per student.

Lesson: (Note: Italicized words are suggestions for language to use during the lesson.)

Lay out the gray Metamorphic Rock Circle*: When we looked at the rock cycle, you saw that there were three types of rocks: Igneous, Sedimentary and Metamorphic. Today we're going to investigate how metamorphic rocks are formed and observe some of the types of metamorphic rock.*

Demonstration(s)

1. **Part one:** Prior to the clay work described below in #3-8, show the students some cake batter. Discuss the consistency of the batter as you pour it into a pan. Put some nuts or raisins on the top and bake in an oven according to directions as you continue with the demonstration.
2. **Part two**: Give pairs of students some clay and ask them to form three 3 cm balls.
3. Give each pair about 30 sequins to mix into one of the balls of clay.
4. Cut this ball in half using a piece of string. Observe and record how the sequins are arranged in the ball of clay.
5. Put this ball back together and stack the three balls one on top of the other with the sequined ball in the middle.
6. Now place the stack of clay balls between two piece of wood and press down on the top to smash the clay together until they are about 3 cm tall altogether.

7. Cut this ball in half with the string. Observe and record the arrangement of the sequins in this new ball.

Discussion

What happened to the liquid cake batter when it was heated?
It dried out, forming bubbles or spaces. The texture changed. (Just as the texture changes when rocks go through metamorphosis.)
What happened to the raisins/nuts? Some of them sank into the cake. (Just as different weights of rock will sink deeper into the earth.)
What do the sequins represent in the ball of clay?
Grains in the rock
What happened to the sequins when pressure was applied?
They flattened out in lines or layers. (Just as grains do in foliated metamorphic rock)
Why do you think this happened?
Do you think rocks might behave similarly?

Metamorphic rocks are formed deep below the surface of the earth where extreme heat and pressure are present. When the plates of the earth's surface collide two things can happen:

1. *The layers push against each other. Folds occur or mountains rise up.*
2. *One layer goes under the other.*

Cookie subduction demonstration

a. *Take apart a sandwich-style cookie with a cream center.*
b. *Using the half that has the cream on top, put the cookie just under your two front teeth. Your front teeth represent one tectonic plate and the cookie represents the other.*
c. *Slowly push the cookie toward the inside of your mouth, while the cream filling is jammed up against your front teeth.*
d. *Have a friend tell you what is happening to the filling.* (It is folding up against your teeth while the cookie is being subducted below.)

This is called subduction. The layer that goes under gets very hot because it is closer to the hot center of the earth. Pockets of magma may get pushed up and the hot magma can have an effect on the rocks that are going under the top layer.

Rocks that are exposed to this kind of heat and pressure change form. "Metamorphic" comes from two Greek words: (See Etymology cards in the materials section.)

Meta means "change"
Morphosis means "form"

Observation of Metamorphic Rocks (This could be a separate lesson.)

1. Lay out three different metamorphic rocks: Ex. Gneiss, Quartzite and Slate (You want to have examples of both foliated and non-foliated metamorphic rocks.
2. Have the students make observations (some have lines in them while others do not.)
3. *Foliated Metamorphic rocks have thin lines that are formed when the grains of the parent rock are heated and put under pressure.*
    a. *How do you think foliated metamorphic rocks will break apart?* Along the grain lines.
    b. *Why?*
4. *When the grains of the parent rock are very fine and weakly cemented, there are no lines. These are called nonfoliated metamorphic rocks.*
    a. *What do you think causes these rocks to have no lines?*
    The particles that form the parent rock recrystallize in the new rock.

Follow-up

1. Put pairs of sedimentary and metamorphic rocks on a 2-compartment tray: sedimentary in one compartment and metamorphic in the other.

2. Have students match the pairs:
   Which sedimentary rock might be the parent rock for which metamorphic rock?

3. Have the students give a rationale for their choices.

Rocks

Lesson/Demonstration #8: Metamorphic Rocks: Degrees of Metamorphosis

Direct Aims:
- To become aware that rocks go through stages of change

Indirect Aims:
- To reinforce earth science concepts
- Classification

Materials
- Chart: A List of Metamorphic Rocks, Parent Materials and Conditions under Which They Change
- Materials for Degrees of Metamorphism
- A sample of these metamorphic rocks: Slate, Phyllite, Schist, Gneiss, Migmatite
- Mudstone or shale
- Limestone and marble, sandstone and quartzite or bituminous and anthracite coal

Lesson: (Note: Italicized words are suggestions for language to use during the lesson.)

Metamorphic Rocks are rocks that started as one kind of rock, were exposed to heat and/or pressure and came out in a changed form.

The amounts of heat and pressure vary greatly depending on the condition that is causing the metamorphism. While there are a number of different conditions that bring about rock changes, there are two that are most common: ***regional metamorphosis*** *and* ***contact metamorphosis.***

Regional Metamorphosis occurs when two continents collide. The rocks pushing against each other cause varying degrees of pressure and heat. It is the rocks themselves that show us how this pressure and heat varies.

Lay out the individual chart pieces: Degrees of Metamorphism: Foliated Metamorphic Rocks

Here we see a progression from the sedimentary rock, shale, through various stages of metamorphism. (Note the progression from shale to slate to phyllite, etc. Lay out each one and describe or show the particular rock. Have the students make observations about the rock: its hardness, color, grain-size, etc.)

Lay out the chart: Degrees of Metamorphism: Foliated Rocks and the Condition under Which They Develop

Here we see the conditions that are present when each type of metamorphic rock changes. The increasing changes are the result of increasing heat and pressure.

Contact metamorphism *occurs when an igneous intrusion comes in contact with "country rock" or the rock that is present around the intrusion.* (Note: If your students have not studied igneous rocks and do not yet understand the intrusive igneous rock that is formed in a pocket of molten lava, you might want to wait for this part of the lesson. Alternatively, you could simply show the material for igneous intrusion and explain that the rising mantle is being contained by the country rock surrounding the igneous pocket.)

The closer to the igneous intrusion the greater the heat. ***Hornfels*** *and skarn, a variation of hornfels, is a metamorphic rock that forms in the intense heat closest to the igneous intrusion.*

From the diagram, you can see the other changes that take place in these conditions: limestone becomes marble, sandstone become quartzite, shale goes through changes that can result anywhere from schist or gneiss to hornfels, and conglomerate becomes metaconglomerate.

Observation of Metamorphic Rocks

Lay out the various pairs of metamorphosed sedimentary rocks and their partner metamorphic rock. Have the students make observations about the appearances.

Follow-up / Shelf Work

1. Put pairs of sedimentary and metamorphic rocks on a 2-compartment tray: sedimentary in one compartment and metamorphic in the other.

2. Have students match the pairs:
   Which sedimentary rock might be the parent rock for which metamorphic rock?
   Have the students give a rationale for their choices.

3. Lay out the various chart pieces and match the rocks to the changes.

Rock vs. Mineral

Lesson/Demonstration #1: Observation and sorting

Rocks and Minerals Lesson Plans give students opportunities to use words to describe visual, textural, and other physical qualities of sample rock specimens. Using compare and contrast skills, students will sort and classify the specimens according to their assessments of the qualities present in each. Students will use simple symbols to create a Venn diagram for classification.

Direct Aims:

- To use observation to sort and classify a group of rocks and minerals
- To use comparisons to make like-characteristic groups

Indirect Aims:

- Preparation for the distinction between mineral (one element or compound) and rock (composed of various minerals).
- Preparation for types of rocks: igneous, sedimentary and metamorphic.
- Hone observation skills, classification skills and organizational skills

Materials Needed:

- A collection of rocks and minerals.
- A magnifying glass for each student.
- Chart paper for recording student observations.
- Small cards to write an observation for sorting.
- Pieces of paper with large shapes for grouping the specimens. (Could be all circles, but of different colors, or could be various geometric shapes. The differences are to emphasize the different characteristics.) (Appendix B)

Lesson: (Note: Italicized words are suggestions for language the teacher may use.)

Lay out the various rocks and minerals to be examined. Choose one and separate it from the rest.

What words would you use to describe this rock? (Color, texture, etc.)

Write the words on the chart paper or on slips of paper.

Choose another rock that shares one quality but not others and repeat this procedure.

Take two of the large shapes. If you haven't already, write the descriptions on slips fo paper, one description per paper.

This rock is black, shiny, and smooth. I'll place the rock and its description inside this large shape.

This rock is black, dull and rough. I'll place the rock and its descriptions inside this large shape.

Move the two shapes toward each other until they over lap a little. Put the descriptors that are the same in the overlapping place (like a Venn Diagram.)

The quality that is the same between these two rocks is the color.

Follow-up

1. Have the children work in pairs to write descriptions and compare their rocks and minerals.
2. Have the students record their observations using a Venn Diagram. (Appendix B.)

Rock vs. Mineral

Lesson/Demonstration #2: One substance vs. Many

In this lesson students continue their visual assessment to distinguish between those rocks that appear to be made of one substance, vs. those that appear to have more than one. This leads to the distinctions that indicate the different types of rocks: igneous, sedimentary and metamorphic. Students come to the label for each type of rock only after they have worked with the specimens and determined the various qualities.

Direct Aims

- To label the distinction between rock and mineral (rock: made of two or more minerals; mineral: made of single element or compound, same throughout)
- To observe and draw conclusions about the visual distinctions between rocks and minerals.

Indirect Aims

- To experience the three types of rocks: igneous, sedimentary and metamorphic
- Observation, classification skills
- Vocabulary development

Materials Needed:

- A collection of rocks and minerals.
- Cards with descriptions for various minerals or rocks.
- Large shapes for grouping the various specimens.
- Magnifying glasses

Lesson: (Note: Italicized words are suggestions for language the teacher may use.)

Today we're going to look for specimens that fit certain descriptions that are written on these cards. They will help us learn the differences between rocks and minerals.

1. Pull out one shape and the card that reads: **Appears to be made of more than one substance.**
2. Have students choose specimens that fit that description and place them inside the shape.

What do you think the different substances could be? (rocks, fossils, minerals)

3. Pull out another shape and the card that reads: **Appears to be made of only one substance.**
4. Have students choose specimens that fit that description and place them inside the shape.

Do any of these specimens look like the substances in the first group? (Students should note the presence of quartz, microcline, feldspar, etc.)

The specimens in the second group are minerals. Minerals are made of just one substance and are the same throughout. If you cut them into pieces they would have exactly the same composition in each piece. The first group is a group of rocks. Rocks are made of at least two substances. Sometimes the substances are tiny grains of sand. Sometimes they are fossils. Sometimes they are different minerals.

Minerals

Defining "mineral" Experiment #1: **Observation of rocks and minerals**.

Materials

- Magnifiers
- Specimens: (Both Rocks and Minerals are needed for this experiment.)

Procedure:

- Using the magnifier, observe each specimen. Some of the specimens are made up of crystals. Crystals are particles that have a geometric shape such as cube, pyramid or double pyramid, or more complex prism.
- Make a chart to identify the specimens that appear to be made of crystals and those that do not. See the example below.

Specimen #	Specimen name	Crystals present?	# crystal types present	Rock or Mineral?

Observation: Minerals are made of only one type of crystal. (Note: This observation could be put on a card for students to copy into their lab book. See "statement" below.)

Statement: Minerals are made of only one type of crystal.

Explanation for the teacher/science behind the work: Many Earth parts are a mixture of different materials. Minerals are made of only one type of crystal material, so there are many parts of the Earth that are not minerals. Rocks are made up of several different types of minerals.

Defining "mineral" Experiment #2: **Forming Mineral Crystals to Compare Halite and Salt**

Materials:

- 2 aluminum pans
- Halite
- Salt
- Teaspoon measure
- Magnifier
- Protective glasses
- Hammer
- Cup
- Masking Tape
- Paper towel
- Black paper

Procedure:

- Use an aluminum dish that is large enough to hold 10 teaspoons of water.
- Label this dish "SALT."
- Put one teaspoon of salt in this dish and add ten teaspoons of warm water.
- Stir until the salt dissolves.
- Wearing protective glasses and using the hammer, break off a small piece of the halite sample.
- Observe the way halite chips. Record your observation or discuss with your lab partner.
- Lightly tap on the halite chip to break it into smaller pieces.
- Put these pieces in a cup and add 5 teaspoons of warm water.
- Stir until the all of the halite dissolves.
- Pour this solution into the other aluminum dish.
- Label this dish "HALITE."
- Put the "SALT" and "HALITE" dishes on a paper towel in a place where they can be undisturbed for 2 to 3 days at room temperature while the water evaporates.
- When the water is gone, use the lab sheet, Comparing Halite and Salt, to direct your observations.

Observation: Complete Lab sheet #2

Explanation for the teacher/science behind the work: Salt crystals are cube-shaped. This fact may be observed in both halite and table salt with a strong enough magnifier. Students may be able to observe cubic shaped crystals in both dishes, but it is likely that the salt crystals will be too small to observe unless you have a very powerful magnifier.

Table salt is sodium chloride. In nature, sodium chloride from saltwater forms large crystals of halite. Halite is crushed to make table salt. Table salt crystals may appear rounded because of this manufacturing process.

Minerals

Defining "mineral" Experiment #3: Variation in Crystal Size due to Slow Evaporation
(Observation to be completed simultaneously with Defining "Mineral," Experiment #4)

Materials:
- Cupric sulfate
- Plastic cup
- Spoon
- Hammer
- Protective glasses
- Several sheets of paper
- Hot water

Form a Hypothesis: What will form in a dish if you let a strong solution of a mineral stand until all the water evaporates?

Procedure:
- Place ½ teaspoon of the cupric sulphate between two sheets of paper. Wearing protective glasses, crush the crystals into small pieces using the hammer.
- Put the crushed crystals into a cup and add 5 teaspoons of hot water.
- Stir until the crystals are dissolved.
- Place the cup in a very cool place where it can remain undisturbed for a week.

Observation: Complete the "Forming Crystals through Slow Evaporation" lab sheet.

Minerals

Defining "Mineral" Experiment #4: **Variations in Crystal Size due to Fast Evaporation**

Materials:

- Cupric sulphate
- Calcite
- Quartz
- Plastic cup
- Spoon
- Magnifier
- Hammer
- Protective glasses
- 2 sheets of paper
- Hot water
- Crystals from Experiment #3

Procedure:

- Place ½ teaspoon cupric sulphate between the sheets of paper and crush the crystals into smaller pieces with the hammer (and wearing protective glasses.)
- Put the crushed crystals into the plastic cup and add 5 teaspoons of hot water.
- Stir until the crystals are dissolved.
- Set the cup in a very warm and undisturbed place for a week.

Observations:

- Complete the Labsheet for Experiment #4: Forming Crystals through Fast Evaporation
- Examine the calcite and quartz crystals, comparing the size of the crystals.

Form a hypothesis about what happened: Based on your observations and comparisons of the Cupric sulphate solution crystals (slow-formed and fast-formed), form a hypothesis to explain the time it took for the crystals to form and the size and number of crystals formed. Which crystal was formed by faster evaporation?

Explanation for the teacher/science behind the work: In experiment #4 the solution was encouraged to evaporate quickly by placing it in a very warm location. The crystals had less time to develop in this condition, so they were smaller but there were more of them. The small the calcite crystals were fomed more quickly than the larger quartz crystals.

Statement: When crystals form more slowly, the individual crystals tend to be bigger and fewer in number than when the crystals form quickly.

Physical Properties of Minerals

Mineralogists use a number of tests on the physical properties of minerals to determine their identity. Some of the tests can be performed easily in the field, while others require laboratory equipment. For the beginning student of geology, there are a number of simple tests that can be used with a good degree of accuracy. The list of tests is in a suggested order, progressing from simple experimentation and observation to more complicated either in procedure or concept.

The following physical properties can be easily used to identify a mineral:

1. Color
2. Streak
3. Hardness
4. Cleavage or Fracture
5. Crystalline Structure
6. Diaphaneity or Amount of Transparency
7. Tenacity
8. Magnetism
9. Luster
10. Odor
11. Taste
12. Specific Gravity

As a particular physical property is discussed, a procedure for determining that property is given. In some cases, these procedures are more specifically outlined as experiments following the description of the physical property.

Physical Properties of Minerals: Color

Most minerals have a distinctive color that can be used for identification. In opaque minerals, the color tends to be more consistent, so learning the colors associated with these minerals can be very helpful in identification. Translucent to transparent minerals have a much more varied degree of color due to the presence of trace minerals. Therefore, color alone is not reliable as a single identifying characteristic.

Procedure for determining Color

Minerals are often associated with particular colors. The geology student should begin to recognize certain colors associated with particular minerals.

When using color, the following are the most common color descriptors:

Colorless	White	Gray
Black	Blue	Green
Yellow	Red	Brown

Modifiers may be added to these basic colors to make more careful distinctions. The modifier may add the name of a familiar object whose color is commonly known, the name of another color with –ish added, or light/dark.

For example: amethyst may be dark purple, sulfur many be lemon yellow, and muscovite mica may be greenish gray.

Color Properties of Minerals

Color is usually the first thing a person notices about a mineral. Color is often the reason a person is attracted to minerals. However, color is not a reliable property to consider for identification purposes and should never be the only property considered in identification. A single variety of mineral can form in several different colors, while many different minerals can form in exactly the same color. It can be confusing and can be the cause of erroneous identification and labeling.

Color in minerals is caused by the absorption and reflection of light waves. When a mineral is in a large crystal form, light is reflected from the surface in a certain way that makes the mineral appear to be a certain color. Pure white light contains bands of wavelengths of all the colors. When the crystal is struck by pure white light, some wave lengths are absorbed by the crystal, while others are reflected back. It is this reflection of wave lengths that gives minerals, and all things in the world, their distinctive colors.

Crystals are made up of combinations of natural elements. A specific variety of mineral, such as quartz, has a specific chemical formula. But trace elements can be present that cause a variation in color. Some elements tend to produce certain colors. Minerals that contain traces of copper tend to be blue to green. Minerals that contain traces of iron tend to be yellow to red to brown. The mineral quartz is famous for all its color variations. The pink color of rose quartz is because of traces of titanium.

When a mineral is rubbed across unglazed porcelain, a fine powder form of the mineral rubs off. These small particles may reflect the light in a different way than a large piece of the mineral. This streak test is a simple way to view the powder form of the mineral; however, streak tests work best with softer minerals (see Mohs Hardness Scale). You can see the powder form of any mineral by breaking off a small chunk and hammering it into powder form (always wearing protective glasses, of course!)

Colors of minerals and mineral streaks are described first using a single color: colorless, white, blue, gray, brown, red, green, yellow, or black. Additional descriptors are added for greater clarification: bluish green, dull red, gray-black, lemon-yellow.

A List of Common Minerals and their Color Descriptions

Mineral	Color Description
apatite	green, blue, yellow, white
barite	colorless to varied colors
biotite mica	green, brown, black
calcite	colorless to white to pale colors
corundum	brown to gray, less often red, blue, brown, yellow
dolomite	buff, gray, white, pinkish
feldspar	salmon-pink, white, gray, green
fluorite	colorless, green, yellow, purple
galena	grayish black (shiny)
garnet	reddish brown, yellowish
graphite	dark gray to black
gypsum: selenite	clear, white, light gray
halite	clear to gray to red
hematite	steel gray, dull red
hornblende (amphibole)	black
kyanite	light blue to greenish blue to blue-gray
magnetite	gray-black
muscovite mica	colorless, silvery white, brownish silvery white
olivine	olive-green to yellow green
plagioclase	white to dark gray
pyrite	brassy-yellow, gold
quartz: amethyst	purple
quartz: rock quartz	clear to milky white
quartz: rose	pink
quartz: smokey	smoky-gray to black
sulfur	pale green to yellow
talc	green, gray, white
topaz	pale yellow, pale blue

Physical Properties of Minerals

Mineral identification Experiment #1: Color

Materials:
- A group of minerals of varying color.
- A set of labels with color names.
- A list of minerals with their color names.

Procedure:
- Lay out the numbered minerals and describe their colors using your own words or ideas.
- Record your description in an observation table like the one below.
- Read the color labels.
- Match the color name labels to the minerals and record these names in your observation table.
- Compare your ideas of the colors to the list of minerals and their colors.
- Record the name of the mineral

Mineral #	Student Color Description	Label Description	Mineral Name

Observation: Answer the lab questions to clarify your observations.

Explanation for the teacher/science behind the work: Color is usually the first thing a person notices about a mineral. Color is often the reason a person is attracted to minerals. However, color is not a reliable property to consider for identification purposes and should never be the only property considered in identification. A single variety of mineral can form in several different colors, while many different minerals can form in exactly the same color. It can be confusing and can be the cause of erroneous identification and labeling.

Color in minerals is caused by the absorption and reflection of light waves. When a mineral is in a large crystal form, light is reflected from the surface in a certain way that makes the mineral appear to be a certain color. Pure white light contains bands of wavelengths of all the colors. When the crystal is struck by pure white light, some wave lengths are absorbed by the crystal, while others are reflected back. It is this reflection of wave lengths that gives minerals, and all things in the world, their distinctive colors.

Crystals are made up of combinations of natural elements. A specific variety of mineral, such as quartz, has a specific chemical formula. But trace elements can be present that cause a variation in color. Some elements tend to produce certain colors. Minerals that contain traces of copper tend to be blue to green. Minerals that contain traces of iron tend to be yellow to red to brown. The mineral quartz is famous for all its color variations. The pink color of rose quartz is because of traces of titanium.

Colors of minerals and mineral streaks are described first using a single color: colorless, white, blue, gray, brown, red, green, yellow, or black. Additional descriptors are added for greater clarification: bluish green, dull red, gray-black, lemon-yellow.

Statement: Minerals come in many colors. Mineralogists use detailed descriptions of the colors to identify certain minerals, but because color can vary, it should not be the only property used for identification.

Physical Properties of Minerals: Streak

Streak is the color of the mineral in powdered form. Streak shows the true color of the mineral. In large solid form, trace minerals can change the color appearance of a mineral by reflecting the light in a certain way. Trace minerals have little influence on the reflection of the small powdery particles of the streak.

The streak of metallic minerals tends to appear dark because the small particles of the streak absorb the light hitting them. Non-metallic particles tend to reflect most of the light so they appear lighter in color or almost white.

Because streak is a more accurate illustration of the mineral's color, streak is a more reliable property than color for identification.

Procedure for determining Streak

Draw the edge of the mineral across an unglazed piece of porcelain Gently blow away any excess powder. The remaining color is a think layer of the mineral and can be used to identify the mineral. This procedure works primarily with minerals of a hardness of 6 or below.

Use only pure specimens for performing this test, as trace elements in the specimen or on the surface can produce different colors than the pure mineral.

Use the terms applied to color to describe the color of the streak.

Physical Properties of Minerals

Mineral Identification Experiment #2: Mineral Property: Streak

Materials

- White streak plate
- Black streak plate
- Various minerals of differing hardness

Form a Hypothesis: Look at the various minerals you will be testing. Make a guess for each of the minerals about the color that will show up on the streak plates. Explain how you decided on each color.

Procedure:

- Scratch each mineral on the white streak plate.
- Scratch each mineral on the black streak plate.
- Observe the color of the streak and record it in a chart like the one below:

Mineral #	Streak color Hypothesis	Streak color on White streak plate	Streak color on Black streak plate	Possible Mineral

Observation: Answer the lab questions to clarify your observations.

Explanation for the teacher/science behind the work: When a clean edge of a mineral is scratched on the surface of an unglazed piece of porcelain (streak plate)**,** a fine dusting of the mineral will remain behind. This is called the "streak." Over time, mineralogists have collected samples and created lists of the colors of the streaks minerals will leave on streak plates. These lists can be used to identify a mineral according to streak color.

Statement: Minerals do not all have the same color streak. Streak color is one quality that mineralogists use to identify minerals.

Physical Properties of Minerals: Hardness

Hardness is one of the better properties to use for identifying a mineral. Hardness is a measure of the mineral's resistance to scratching. The Mohs scale is a set of 10 minerals whose hardness is known. The softest mineral, talc, has a Mohs scale rating of one. Diamond is the hardest mineral and has a rating of ten. Softer minerals can be scratched by harder minerals because the forces that hold the crystals together are weaker and can be broken by the harder mineral.

The following is a listing of the minerals of the Mohs scale and their rating:

1. Talc
2. Gypsum
3. Calcite
4. Fluorite
5. Apatite
6. Orthoclase Feldspar
7. Quartz
8. Topaz
9. Corundum
10. Diamond

Procedure for determining Hardness

Use various minerals to see if one will scratch the other. Since harder minerals scratch softer minerals, you can use this to put minerals in a softer to harder order. However, without a set of reference minerals, you will not be able to clearly define the hardness.

Hardness of minerals can also be tested using some common, readily available substances. This is called a **field scale of hardness.**

- Hardness of 1-------------Mineral rubs off on the fingers
- Hardness of 2-------------Mineral can be scratched with a finger nail (Mohs hardness of 2.5)
- Hardness of 3-------------Mineral can be scratched with a copper coin (Mohs hardness of 3.5)
- Hardness of 4 to 5--------Mineral can be scratched with a nail. (Mohs hardness of 4.5)
- Hardness of 5-------------Mineral can be scratched with glass (Mohs hardness of 5.5)
- Hardness of 6 to 7--------Mineral can be scratched with a quartz crystal (Mohs hardness of 7)

Some caution needs to be taken in making a determination as the degree of hardness can be affected by the following situations:

- The surface being tested needs to be a fresh, clean surface.
- Determine if the surface being tested is being scratched or if it is breaking along cleavage lines.
- The testing surface should be smooth as rough surfaces may scratch too easily because the points of crystals on the rough surface are being fractured.
- Test several different surfaces, because different surfaces can have different hardness.

Physical Properties of Minerals: Cleavage & Fracture

Minerals tend to break along lines or smooth surfaces when hit sharply. Different minerals break in different ways showing different types of cleavage.

Cleavage is defined using two sets of criteria. The first set of criteria describes how easily the cleavage is obtained. Cleavage is considered perfect if it is easily obtained and the cleavage planes are easily distinguished. It is considered good if the cleavage is produced with some difficulty but has obvious cleavage planes. Finally it is considered imperfect if cleavage is obtained with difficulty and some of the planes are difficult to distinguish.

The second set of criteria is the direction of the cleavage surfaces. The names correspond to the shape formed by the cleavage surfaces: Cubic, rhombohedral, octahedral, dodecahedral, basal or prismatic. These criteria are defined specifically by the angles of the cleavage lines as indicated in the chart below:

Cleavage Type	Angles
Cubic	Cleaves in three directions @ 90^o to one another
Rhombohedral	Cleaves in three directions but not @ 90^o to one another
Octahedral	Cleaves in four directions
Dodecahedral	Cleaves in six directions
Basal	Cleaves in one direction
Prismatic	Cleaves in two directions

Fracture describes the quality of the cleavage surface. Most minerals display either uneven or grainy fracture, conchoidal (curved, shell-like lines) fracture, or hackly (rough, jagged) fracture.

Physical Properties of Minerals: Crystalline Structure

Mineral crystals occur in various shapes and sizes. The particular shape is determined by the arrangement of the atoms, molecules or ions that make up the crystal and how they are joined. This is called the **crystal lattice**. There are degrees of crystalline structure, in which the fibers of the crystal become increasingly difficult or impossible to see with the naked eye or the use of a hand lens. M**icrocrystalline** and **cryptocrystalline** structures can only be viewed using high magnification. If there is no crystalline structure, it is called **amorphous**. However, there are very few amorphous crystals and these are only observed under extremely high magnification.

Procedure for identification of Crystalline Structure

Hold the crystal in good direct light. Look at the mineral closely using a hand lens. Look for smooth, flat surfaces. Flat surfaces may be either the result of breaking along cleavage planes or crystal faces. Either way, flat surfaces mean that the mineral is crystalline.

Crystallinity or Crystal Form: If the arrangement of the crystal has symmetry, the characteristic is called **crystallinity**. There are seven crystal systems defined by the geometrical arrangement of the crystal lattice. (See chart.) It is difficult, when finding a mineral in the field, to determine the difference between a crystal face, a naturally occurring formation, and cleavage planes created by breaking. Crystal faces cannot be reproduced by breaking, while cleavage planes are the result of breaking and can be reproduced over and over. Another difficulty in the field is finding a mineral specimen that has the complete crystal form.

Procedure for identification of Crystal Form

First, identify crystal faces and cleavage planes. Crystal faces are usually very smooth, while cleavage planes are less so. It is rare that a cleavage plane is a smooth as the naturally occurring crystal face. Identify the geometric shape that corresponds to one of the seven crystal systems. Once you have matched the external geometric shape, you can begin to identify planes of symmetry, axes of symmetry and find the center of symmetry.

NOTE: The study of Crystal Structure and Form is a study unto itself and will be explored in future versions of this publication. In the meantime, please refer to the following websites for extensions:

www.science**kids**athome.com/science_topics/what_are_**crystals**.html

www.nationalgeographic.com/ng**kids**/trythis/tryfun1.html

http://chemistry.about.com/od/crystalsforkids/Crystal_Projects_for_Kids.htm

Physical Properties of Minerals: Transparency or Diaphaneity

Diaphaneity is a mineral’s degree of transparency or ability to allow light to pass through it. The degree of transparency may also depend on the thickness of the mineral.

Procedure for determining Diaphaneity

Observe the mineral at both its thin edges and the thicker parts. Orient the mineral to the light so that either the light or an image behind it may be seen through.

Term	Description
Transparent	The mineral can transmit both clearly defined image and light.
Subtransparent	The mineral can transmit indistinct outlines of an image and light.
Translucent	The mineral can transmit light but not an image.
Subtranslucent	The mineral can transmit light only at thin edges.
Opaque	The mineral can transmit neither image nor light.

Physical Properties of Minerals: Tenacity

Tenacity is the characteristic that describes how the particles of a mineral hold together or resist separation. The chart below gives the list of terms used to describe tenacity and a description of each term.

Term for Tenacity	Definition
Friable	Easily broken or crumbled under pressure of the hand
Brittle	Crumble under a knife or hammer, but not fragile
Sectile	Can be cut with a knife without breaking off in pieces
Malleable	Can be hammered into thin sheets
Flexible	Will bend under stress and will not return to original shape
Elastic	Will bend under stress but will return to original shape
Tough	Resists stress without breaking or coming apart

Procedures for Determining Tenacity

1. Gently put pressure on the mineral by squeezing between the thumb and index finger.
   - If the mineral changes shape, does not return to its previous shape, and does not break, it is **flexible.**
   - If the mineral changes shape, but returns to its previous shape, it is **elastic.**
   - If the mineral crumbles, it is **friable.**

2. Place the mineral on a flat steel surface or cutting board. Use a knife to gently apply pressure to the mineral as if to cut it.
   - If the mineral crumbles, it is **brittle.**
   - If the mineral cuts into two pieces, it is **sectile**.

3. Place a small piece of the mineral on a flat steel surface or cutting board. Tap it lightly with a hammer. If the mineral flattens, it is **malleable**.

Physical Properties of Minerals: Magnetism

Magnetism is the characteristic that allows a mineral to attract or repel other magnetic materials. It can be difficult to determine the differences between the various types of magnetism, but it is worth knowing that there are distinctions made.

The chart below describes the different types of magnetism that can be observed in minerals.

Ferromagnetic	These minerals are strongly attracted by a magnet.
Paramagnetic	These minerals are weakly attracted by a magnet.
Diamagnetic	These minerals are weakly repelled by a magnet.
Ferromagnetic and Magneto-dipolar	These minerals are magnetic and hold their magnetism for a period of time after being magnetized.

Procedure for determining Magnetism

1. Place a paper clip on the table.
2. Hang a second paper clip on a piece of string and slowly move it downward toward the first paper clip. If the two paper clips attract each other, then they have been magnetized and are not useful in this experiment. Continue trying paper clips until you find one that has NO magnetic charge.
3. Place the paper clip that has NO magnetic charge on the table. Slowly move the mineral from several inches above the paper clip downward toward the paper clip. If the paper clip moves, then the mineral is ferromagnetic and magneto-dipolar.

Testing for ferromagnetism:

1. Magnetize a paper clip by rubbing it across a permanent magnet.
2. Hang the paper clip on a piece of string or a toothpick.
3. Move the mineral specimen close to the paper clip. If the paper clip moves, the mineral is ferromagnetic.

Physical Properties of Minerals: Luster

Luster is the physical property that indicates how much the surface of a mineral reflects light. The luster of a mineral is affected by the brilliance of the light used to observe the mineral surface. Luster of a mineral is described in the following terms:

Metallic	The mineral is opaque and reflects light as a metal would.
Submettalic	The mineral is opaque and dull. The mineral is dark colored.
Nonmettalic	The mineral does not reflect light like a metal.

Nonmetallic minerals are described using modifiers that refer to commonly known qualities.

Waxy	The mineral looks like paraffin or wax.
Vitreous	The mineral looks like broken glass.
Pearly	The mineral appears iridescent, like a pearl.
Silky	The mineral looks fibrous, like silk.
Greasy	The mineral looks like oil on water.
Resinous	The mineral looks like hardened tree sap (resin).
Adamantine	The mineral looks brilliant, like a diamond.

Procedure for determining Luster

Hold the mineral in a bright light. Make sure you have a clean, freshly broken surface. Rotate the mineral in the light, observing how the surface reflects light. If light bounces off the surface like it would off a coin or a knife, then it is metallic. If the mineral is determined to be nonmetallic, then add another modifier to more clearly describe the quality of the reflection.

Note: Metallic and submetallic minerals tend to have a high specific gravity.

Physical Properties of Minerals: Odor

Most minerals have no odor unless they are acted upon in one of the following ways: moistened, heated, breathed upon, or rubbed.

Procedure for determining Odor

Breathe on the mineral or lightly moisten the surface with water.
Move the mineral back and forth about an inch below your nose.
Compare the odor with the following chart of descriptors:

Alliaceous	The mineral smells like garlic.
Fetid	The mineral smells like rotten eggs. .
Sulphurous	The mineral smells like burning sulfur.
Argillaceous	The mineral smells like moistened clay.
Bituminous	The mineral smells like bitumen, or petroleum.

Physical Properties of Minerals: Taste

Only soluble minerals have a taste, but it is very important that minerals not be placed in the mouth or on the tongue. You should not test for this property in the classroom.

Mineral taste can be described as follows:

Saline	The mineral tastes salty.
Sweetish astringent	The mineral tastes like alum.
Alkaline	The mineral tastes like baking soda.
Cooling	The mineral tastes like saltpeter.
Bitter	The mineral tastes like Epsom Salt.
Sour	The mineral tastes like lemon.

Physical Properties of Minerals: Specific Gravity

Specific Gravity of a mineral is a comparison or ratio of the weight of the mineral to the weight of an equal amount of water. The weight of the equal amount of water is found by finding the difference between the weight of the mineral in air and the weight of the mineral in water.

Procedure for determining Specific Gravity

First, check to make sure the mineral is not water soluble. Place the corner or edge of the mineral slightly into a beaker of water and look for one of the following behaviors:

1. Small pieces of the mineral are breaking off and falling into the water. This means the mineral is disintegrating.
2. The water around the edge of the mineral is swirling like it does just before boiling. This is called turbidity and it indicates the mineral is dissolving.

Once you have determined the mineral is not water soluble, tie a string around the mineral and attach it to a beam balance to determine the mass in air. Record the weight.

Next place a beaker of water under the mineral until the mineral is completely submerged. Record the weight.

Finally, do the following calculations to determine the specific gravity:

1. Subtract the weight of the mineral in water from the weight of the mineral in air.
2. Divide the weight of the mineral in air by the difference you have just found.

$$\text{Specific Gravity} = \frac{\text{Weight of the mineral in air}}{\text{Weight of the mineral in air} - \text{weight of the mineral in water}}$$

Appendix A: Lab Sheets

Name: _______________________ Date: __________

Grains of Sand
Labsheet

After you have drawn a chart of your data, answer these questions to help you identify the types of minerals present in the sand.

1. Did you notice different colors to the grains of sand? List the colors you observed.

2. Did you notice different luster to the various grains of sand? Describe the different lusters you observed.

3. Some minerals *cleave* or break evenly along edges resulting in smooth, flat surfaces. Did you see any grains that appeared to have smooth, flat surfaces? Describe them.

4. Some minerals *fracture* or break unevenly, resulting in rough edges and irregular shapes or chunks. Did you see any grains that appeared to have rough edges or irregular shape? Describe them.

5. Were you surprised about how many different types of grains there were in the sand sample? ___________

6. How many different minerals made up the grains of your sand specimen? ___

7. Use the chart of mineral descriptions to help you decide which mineral grains were in your sand specimen. Make a list on a separate piece of paper.

Name: ____________________________ Date: __________

Defining "Mineral"
Labsheet
Experiment #1: Observation of Rocks and Minerals

Specimen #	Specimen name	Crystals present?	# crystal types present	Rock or Mineral?

Name: ______________________________ Date: __________

Defining "Mineral"
Labsheet
Experiment #2: Forming Mineral Crystals: Comparing Halite and Salt

1. Use a magnifier to observe the crystals at the bottom of each aluminum dish. How do the crystals compare with one another? Are they the same or different? Record your observation, including a drawing of an individual crystal, here:

2. Wet your finger and touch it to the crystals in the "SALT" dish. Taste the crystals on your finger. Repeat this procedure with the crystals in the "HALITE" dish. How do the tastes compare? Are they the same or different? Record your observation here:

3. Wet the large chunk of halite and touch it with your finger. How does this taste compared to the crystal samples in your dishes? Record your observations here:

4. Pick out the largest, most distinct crystals from each of your aluminum dishes. Place these on black paper. Pour a few grains of table salt onto the black paper near your crystals. Use the magnifier to compare the various crystals. Record your observations here:

5. Based on the observations you made, how would you guess that halite is formed?

Name: ____________________________ Date: __________

Defining "Mineral"
Labsheet
Experiment #3: Forming Crystals through Slow Evaporation

Complete this worksheet about a week after setting up the cupric sulphate solution.

Observe the crystals in the cup after the water is completely evaporated. Answer the following:

1. What color are the crystals in the cup?

2. What shape are the crystals? (Use a magnifier if necessary.)

3. How does this shape compare with the shape of the halite or table salt crystals?

4. Count the number of crystals formed and record the number here: _______________

5. Measure the size of the crystals and record the measurement(s) below:

Crystal	Size
#1	
#2	
#3	
#4	
#5	

6. Compare the crystals formed by the cupric sulphate solution and the original cupric sulfate crystals. The blank spaces are for your own criteria.

	Original Cupric Sulphate Crystals	Cupric Sulphate Solution Crystals
Color		
Size		
Number		

Name: ___________________________ Date: ____________

Defining "Mineral"
Labsheet
Experiment #4: Forming Crystals through Fast Evaporation

Complete this worksheet about a week after setting up the cupric sulphate solution.

Observe the crystals in the cup after the water is completely evaporated. Answer the following:

1. What color are the crystals in the cup? ____

2. What shape are the crystals? (Use a magnifier if necessary.) ____________________________

3. How does this shape compare with the shape of the halite or table salt crystals?

4. Count the number of crystals formed and record the number here: _______________

5. Measure the size of the crystals and record the measurement(s) below:

Crystal	**Size**
#1	
#2	
#3	
#4	
#5	

6. Compare the crystals formed by the slow-evaporating solution and the crystals formed by the fast-evaporating solution. The blank spaces are for your own criteria.

	Slow-evaporating Cupric Sulphate Solution Crystals	**Fast-evaporating** Cupric Sulphate Solution Crystals
Color		
Size		
Number		

Name: ______________________________ Date: __________

Mineral Identification
Labsheet
Experiment #1: Using Color as a Physical Property for Identification

Mineral #	Student Color Description	Label Description	Mineral Name

Answer these questions to clarify your observations.

1. In general, how many words did you use to describe each mineral?

2. In general, how many words did mineralogists use to describe each mineral?

3. Do you think the mineralogists' descriptions were accurate?

4. How would you change one of the mineralogists' descriptions to more accurately describe your mineral? Write your description here:

5. What is your explanation for why the minerals are not all the same color?

Name: ____________________________ Date: __________

Mineral Identification
Labsheet
Experiment #2: Using Streak as a Physical Property for Identification

Scratch each mineral on a white streak plate and on a black streak plate.
Blow off any excess powder before naming the color of the streak.

Be sure you use a clean edge of the mineral. The streak color can be affected by oxidation on the surface of the mineral.

Mineral #	Streak color Hypothesis	Streak color on White streak plate	Streak color on Black streak plate	Possible Mineral

Answer these questions to help you make observations. When you are finished, use the Physical Properties of Minerals to Identify the minerals you tested.

6. Did the minerals have the same streak color on the white streak plate?

7. Did the minerals have the same streak color on the black streak plate?

8. Did the color of the streak match the color of the mineral?

9. Why do you think this is true?

10. Why didn't the minerals all have the same streak color?

Appendix B: Materials to Accompany the Lessons

Note: These cards are for matching to color-coded marbles per the lesson description. There are cards with names and symbols in matching colors and black cards for a greater level of abstraction. After these matching cards you will find 3 task cards to go with the lesson for follow-up. There are also two blank cards for you to use to make your own follow-ups.

Oxygen **O** **46.4%**	**Sodium** **Na** **2.4%**	**Aluminum** **Al** **8.2%**
Silicon **Si** **28.2%**	**Iron** **Fe** **5.6%**	**Magnesium** **Mg** **2.3%**
Potassium **K** **2%**	**Calcium** **Ca** **4.2%**	

Oxygen **O** **46.4%**	**Aluminum** **Al** **8.2%**	**Potassium** **K** **2%**
Iron **Fe** **5.6%**	**Magnesium** **Mg** **2.3%**	**Calcium** **Ca** **4.2%**
Silicon **Si** **28.2%**	**Sodium** **Na** **2.4%**	

Eight Basic Earth Elements – Card 1

Match the colored marbles with the colored cards for the elements.

Make a table like the one below in your notebook or on graph paper.

Record all the requested data in your table.

Element Name	Symbol	# marbles	% of Earth Elements
Oxygen	O	47	46.4%

Eight Basic Earth Elements – Card 2

Complete the following in your notebook or on graph paper.

1. List the Eight Basic Earth Elements in alphabetical order.
2. Record the quantity percentages for each element in a second column.
3. Add the percentages.
4. Does the total equal 100%?
5. What does the difference between your total and 100% represent?

Eight Basic Earth Elements – Card 3 (front)

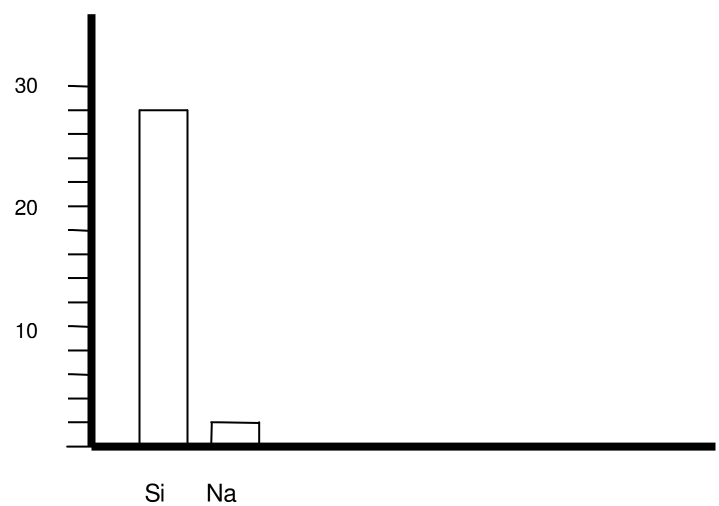
Bar graph of the Eight Basic Earth Elements.

A Bar Graph is an easy way to compare different quantities. In this exercise, you will make a bar graph to compare the different quantities of earth elements.

1. Draw two heavy black lines: a vertical line along the left side of your paper and a horizontal line near the bottom. Leave about 1 ½ inches on the left of the vertical line and below the horizontal line.
2. The vertical line will be divided into equal amounts for the percentages. The biggest number you need is 50%. The smallest is 0%. Mark off regular intervals for the percentages on the vertical line.
3. The horizontal line will be divided into 8 equal columns for the 8 elements plus one column for all other elements. Divide the horizontal line into 8 equal columns. Label the columns below the heavy line using the symbol for each element.
4. Mark the percentages for each element in the appropriate column.
5. Color the column using the colors of the marbles.
6. Write a Title on the top of your bar graph.

Eight Basic Earth Elements – Card 3 (back)

Example:



Photos of Erupting Volcanoes and Flows

April 1986, Pu'u O'o Eruption, Kilauea Volcano, Hawaii,
USGS http://vulcan.wr.usgs.gov/Volcanoes/Hawaii/VisitVolcano/framework.html

USGS Scientist examines pyroclastic flow on Mt. St. Helens, Washington
USGS http://vulcan.wr.usgs.gov/Volcanoes/MSH/Images/pyroclastic_flows.html

Aerial view of Mt. St. Helens pyroclastic flows, October, 1980
USGS http://vulcan.wr.usgs.gov/Volcanoes/MSH/Images/pyroclastic_flows.html

Mt. St. Helens pyroclastic eruption;
USGS http://vulcan.wr.usgs.gov/Volcanoes/MSH/Images/pyroclastic_flows.html

Photographs of Types of Volcanoes

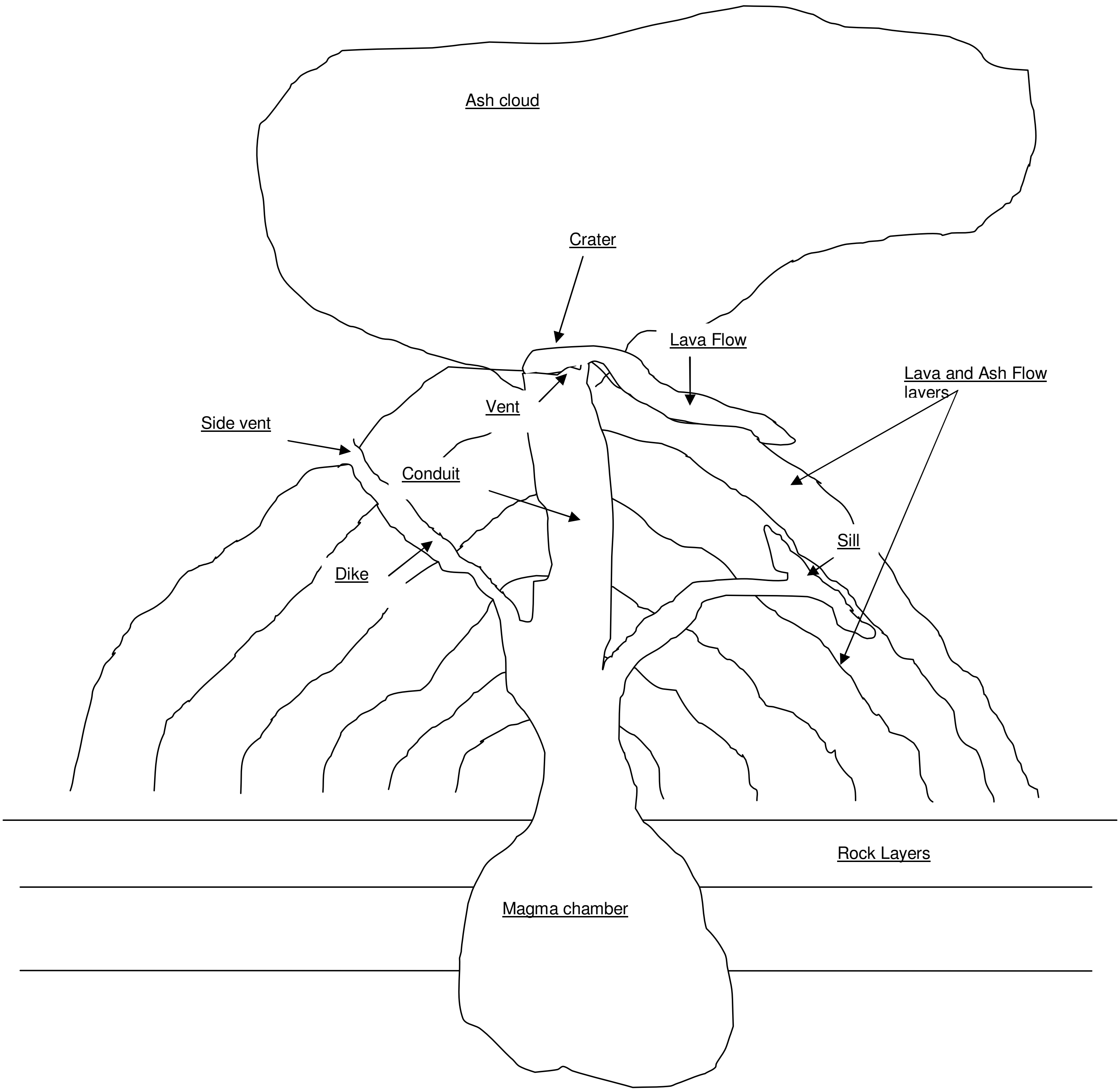
A Composite Volcano: Mt. St. Helens, Washington,
Image courtesy of USGS /Cascades Volcano Observatory; <http://vulcan.wr.usgs.gov/home.html>

A shield volcano: Mt. Bachelor, Oregon
Photo courtesy of USGS/Cascade Volcano Observatory; <http://vulcan.wr.usgs.gov/home.html>

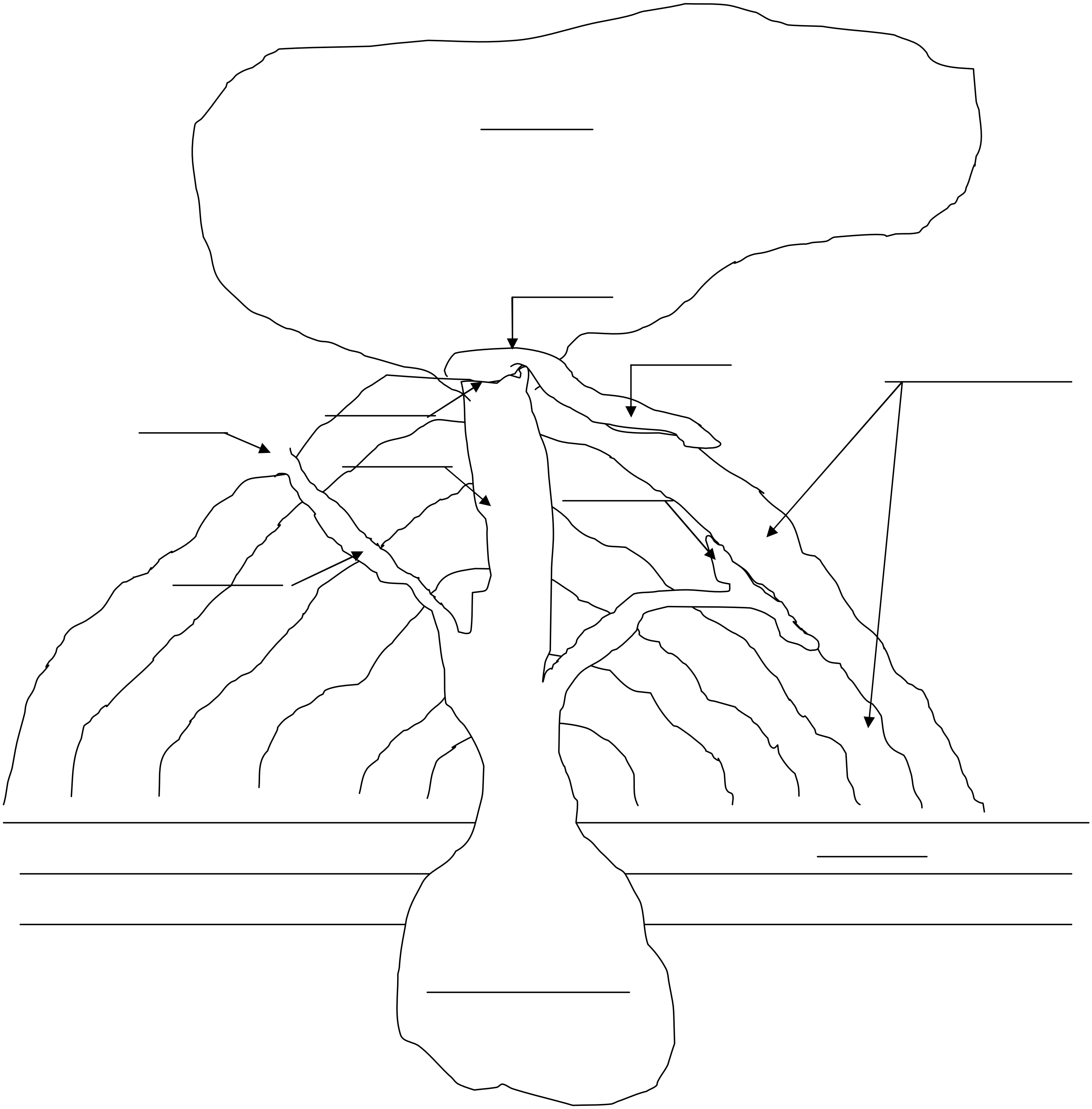
A shield volcano: Mauna Loa, Hawaii
Courtesy of USGS/ Cascade Volcano Observatory ; <http://vulcan.wr.usgs.gov/home.html>

A Cinder Cone: Pilot Butte north of Bend, Oregon
Photo courtesy of USGS/Cascade Volcano Observatory; <http://vulcan.wr.usgs.gov/home.html>

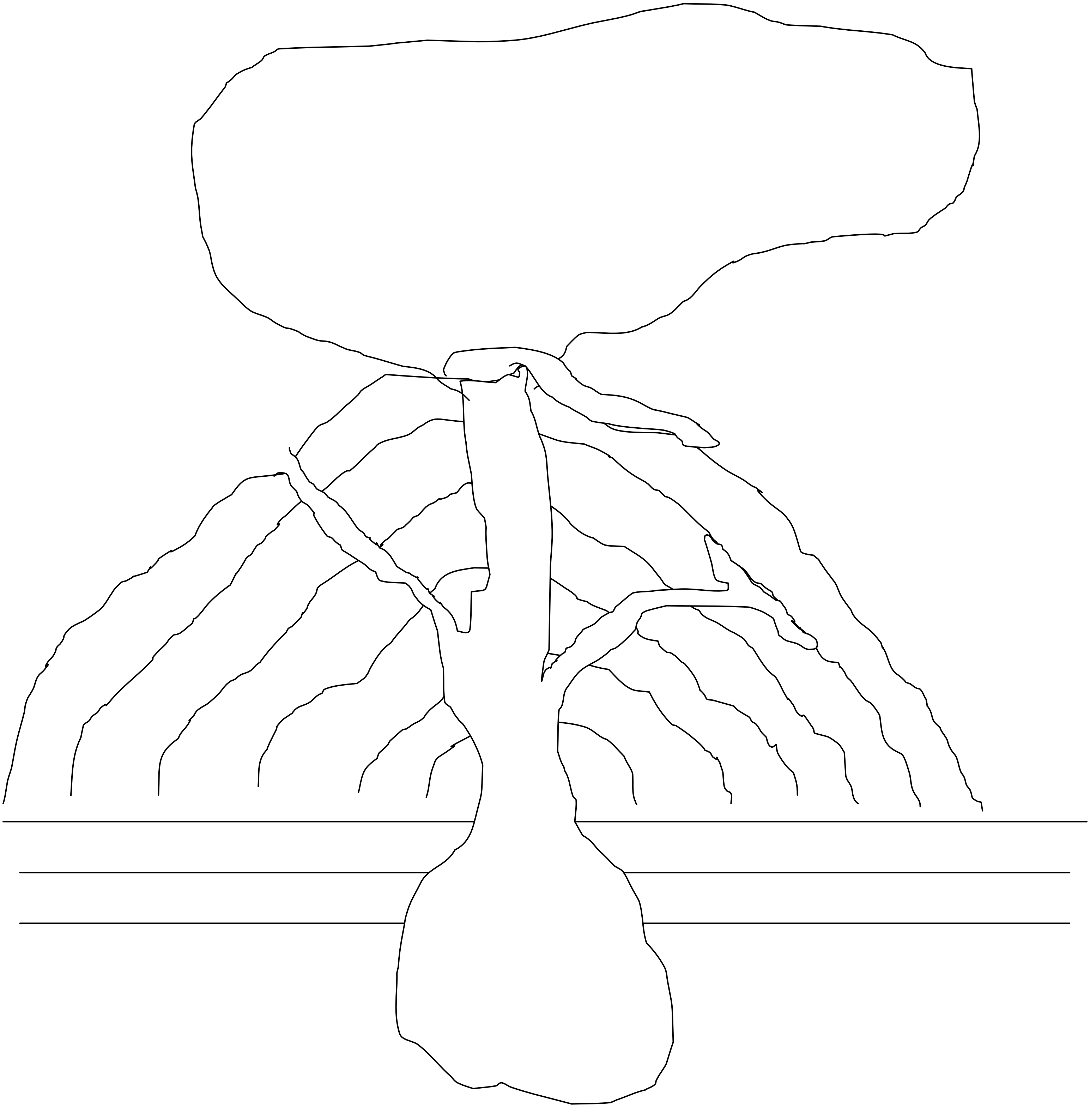

View east across Haleakala Crater, with young cinder cones in foreground.
Photo courtesy of USGS/Hawaiian Volcano Observatory http://hvo.wr.usgs.gov/volcanoes/haleakala/main.html


Ash cloud
Crater
Lava Flow
Lava and Ash Flow layers
Side vent
Vent
Conduit
Sill
Dike
Rock Layers
Magma chamber

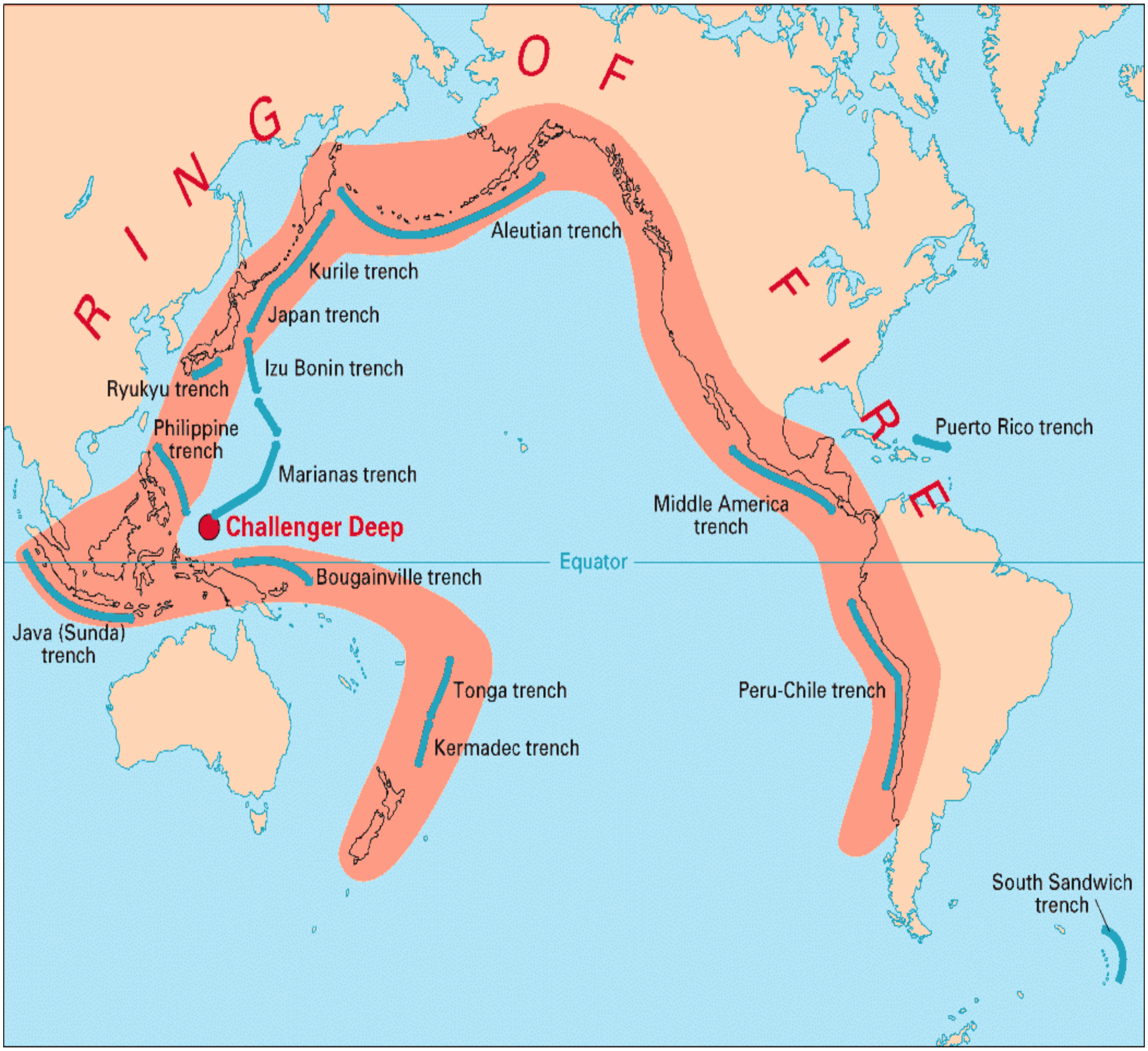
m



n



The Volcanic Ring of Fire

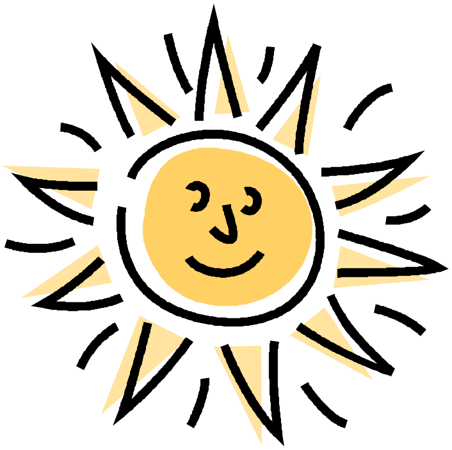


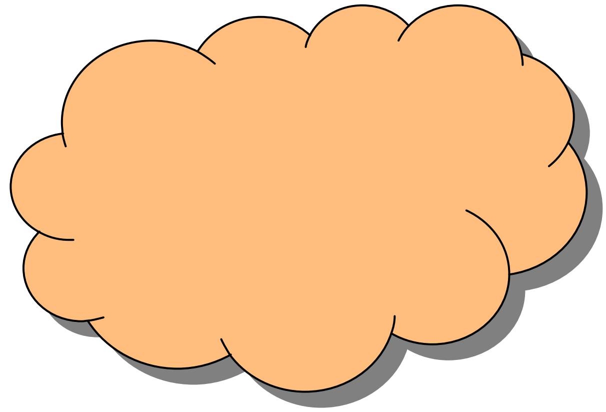
From United States Geological Survey: URL: http://pubs.usgs.gov/publications/text/fire.html

Cards for the discussion of weather

precipitation

wind





sunshine cloud

temperature

Photographs of Weathering

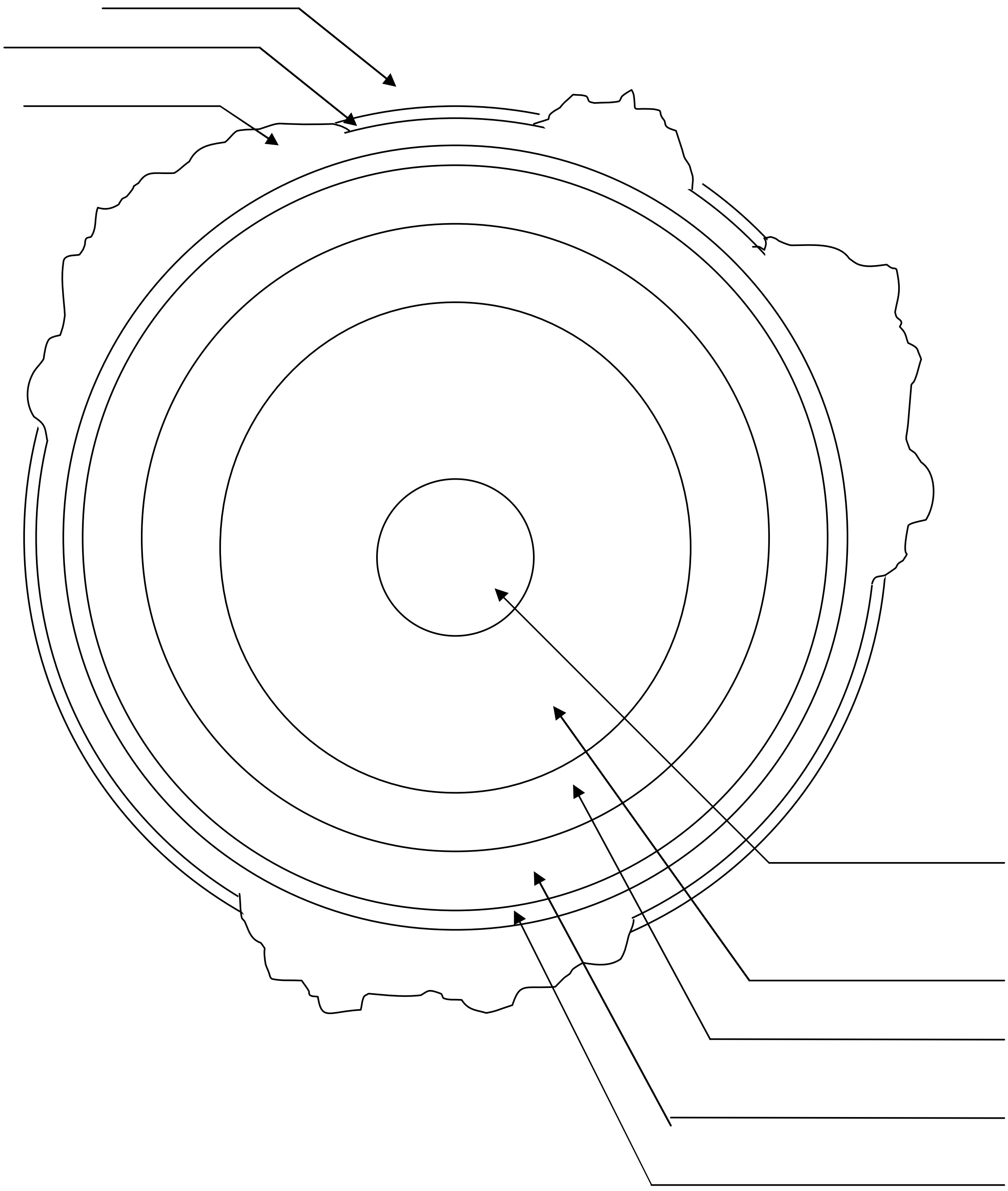
Storm near Elko, NV (NOAA), Courtesy of USGS (United States Geological Survey)
http://ga.water.usgs.gov/edu/watercycleprecipitation.html

From: "Erosion: Why it happens and What to do about it"; Photo taken by Dr. Judi Earl; used with permission http://managingwholes.com/photos/erosion/index.htm

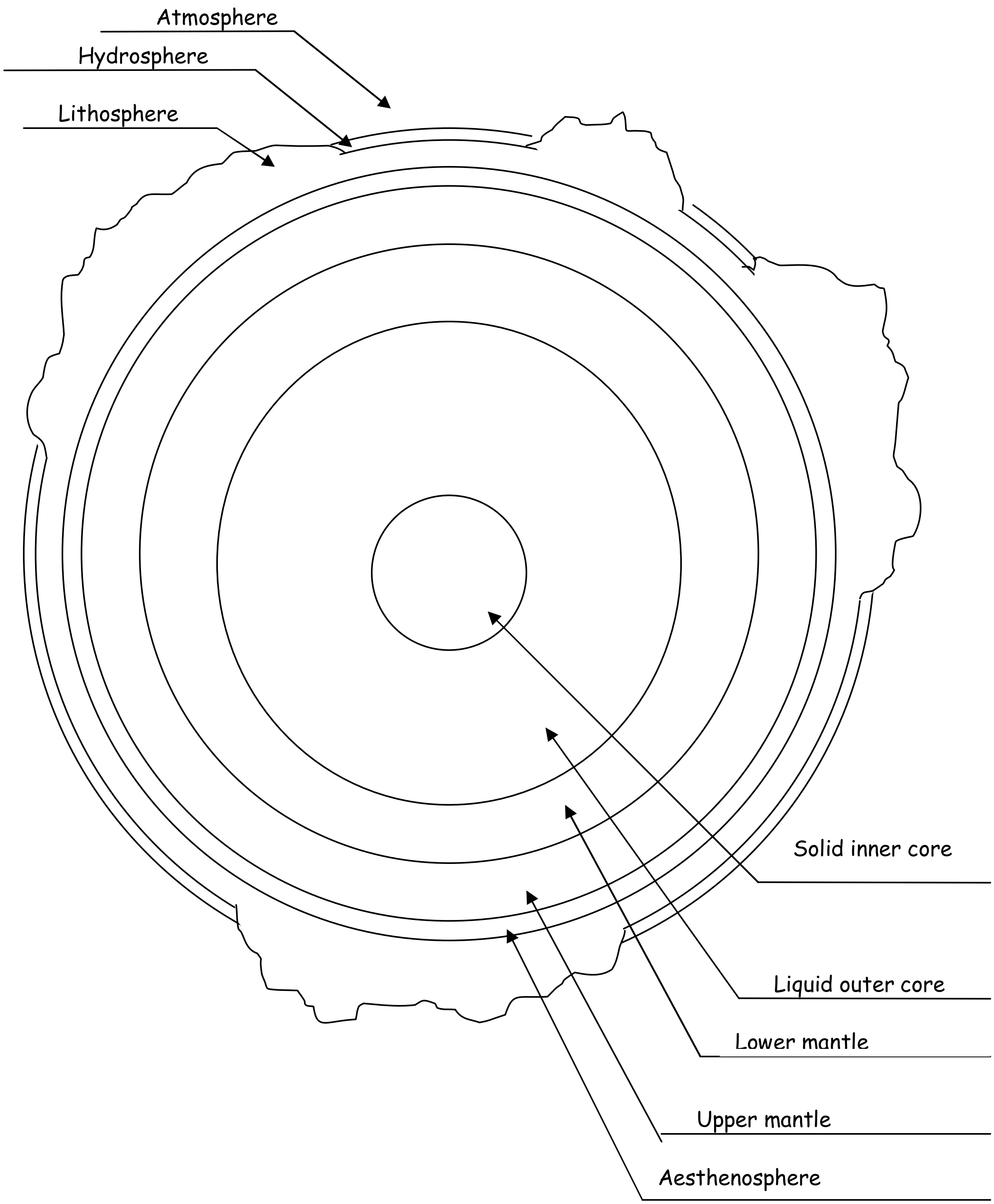
From: "Erosion: Why it happens and What to do about it"; Photo courtesy of Wilma Keppel; used with permission; http://managingwholes.com/photos/erosion/index.htm

The massive sediment in the background is a poorly-sorted till, deposited at the base of the now-thinning and retreating casement glacier. The boulders in the foreground are a lag deposit resulting from the removal of the finer grain-sizes in the till by the ice-marginal stream. Glacier Bay National Park, Alaska Photo courtesy of USGS (United States Geological Survey) **pubs.usgs.gov/of/2004/1216/tz/tz.html**

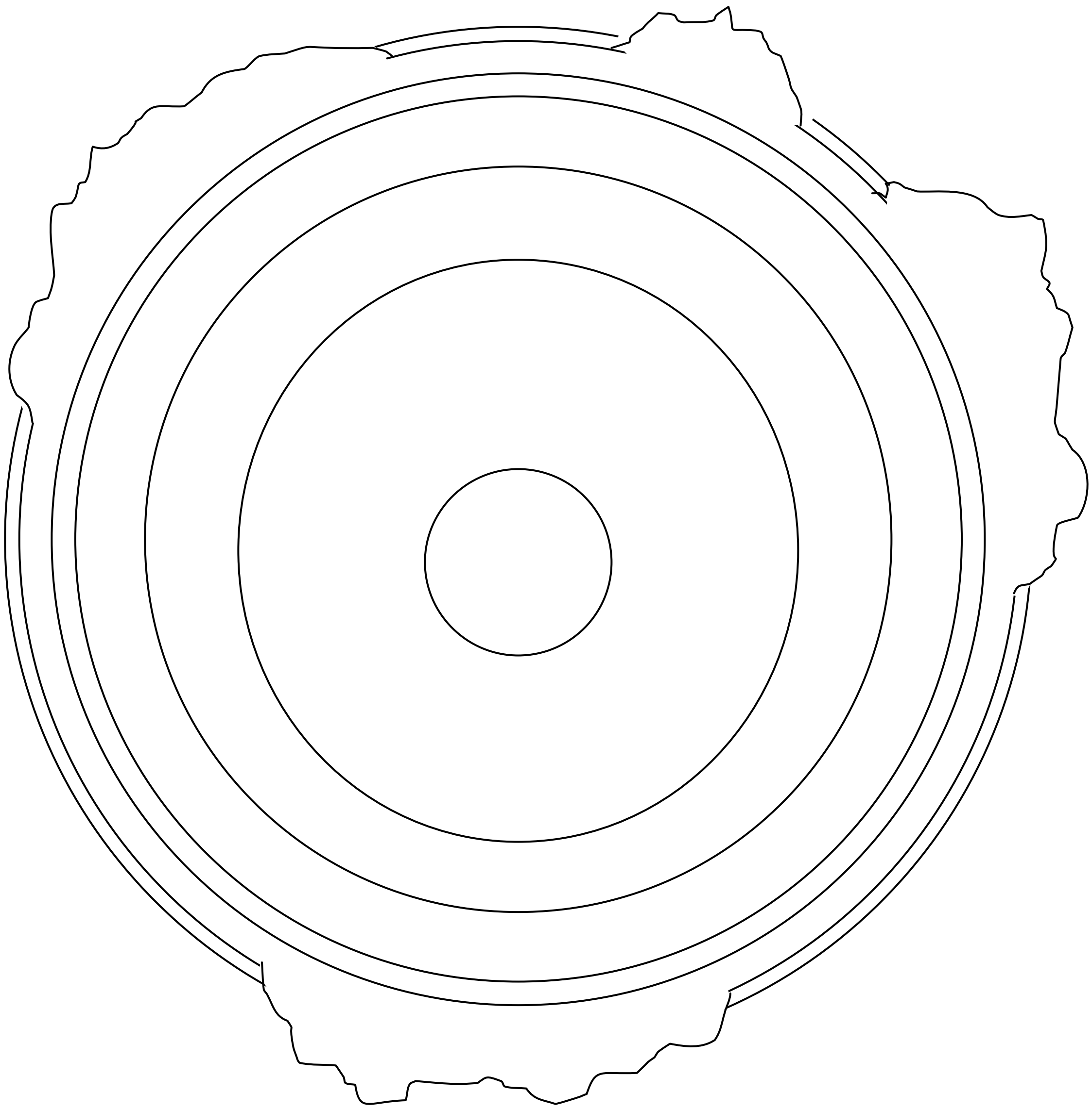
Layers of the Earth



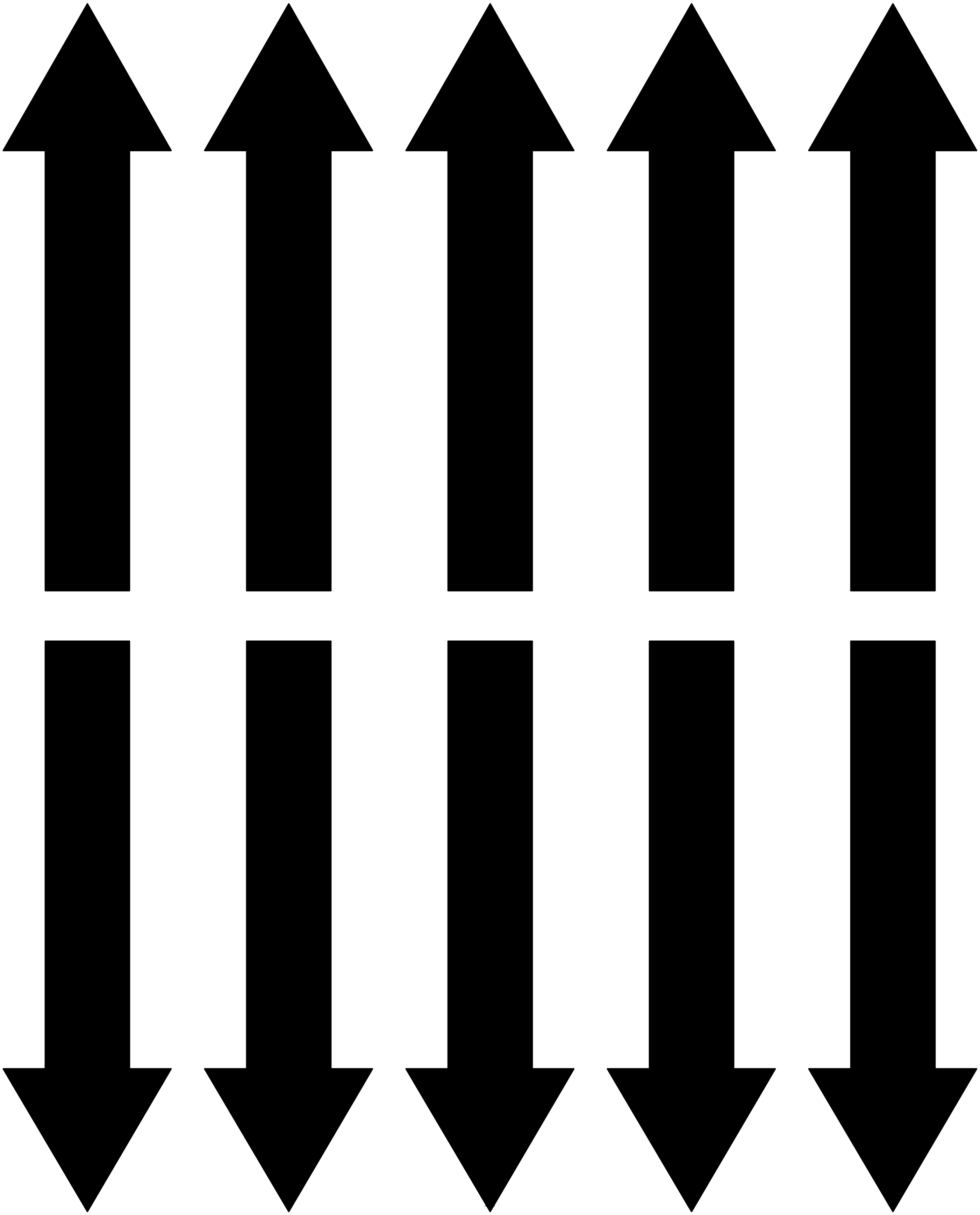
Layers of the Earth



Layers of the Earth



Arrows for convergent – divergent



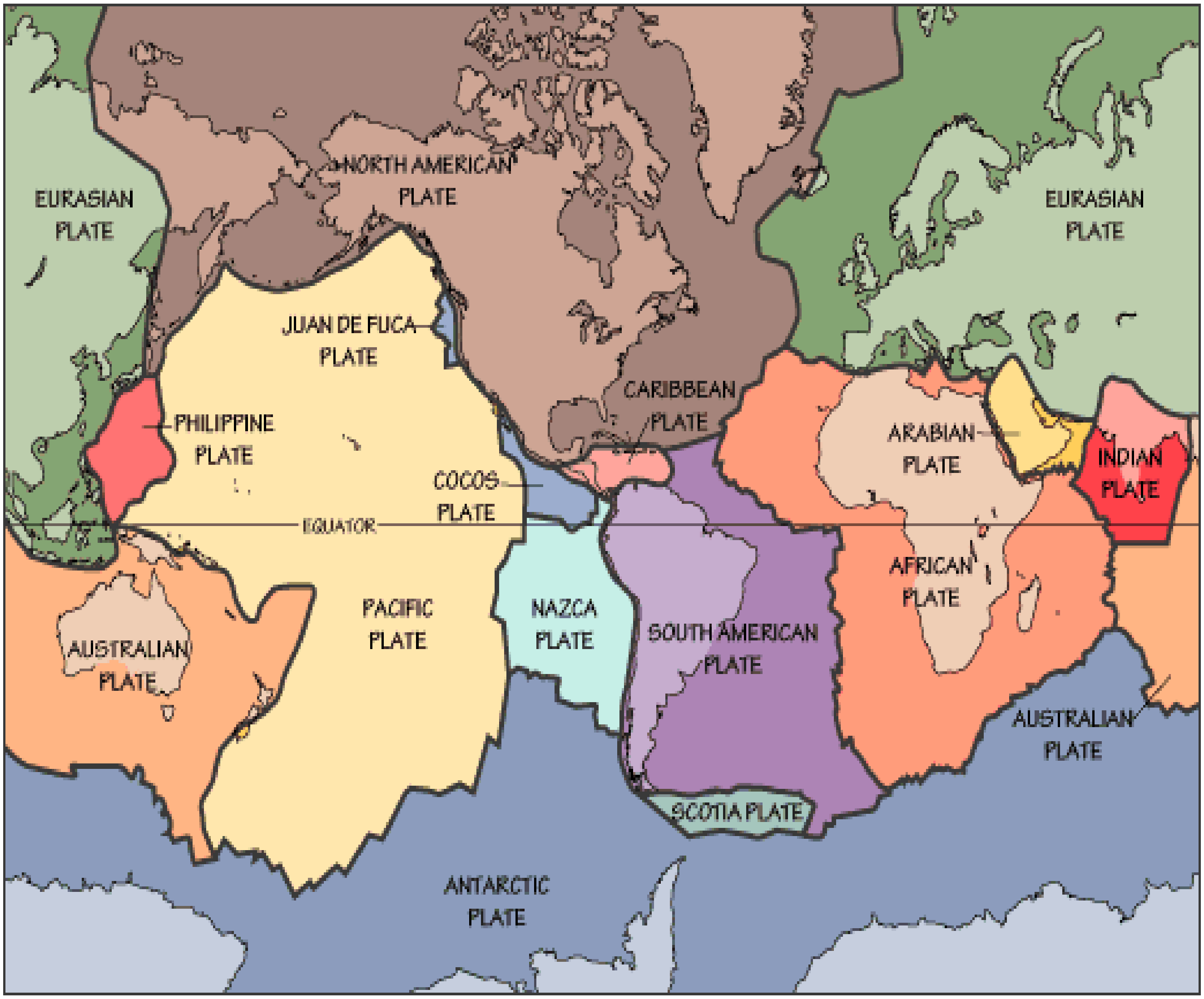


Plate map courtesy of the USGS (United States Geological Survey: http://pubs.usgs.gov/gip/dynamic/slabs.html
Arrows indicate direction of plate movement as collected from various tectonic maps available online and in research materials listed in the References section.

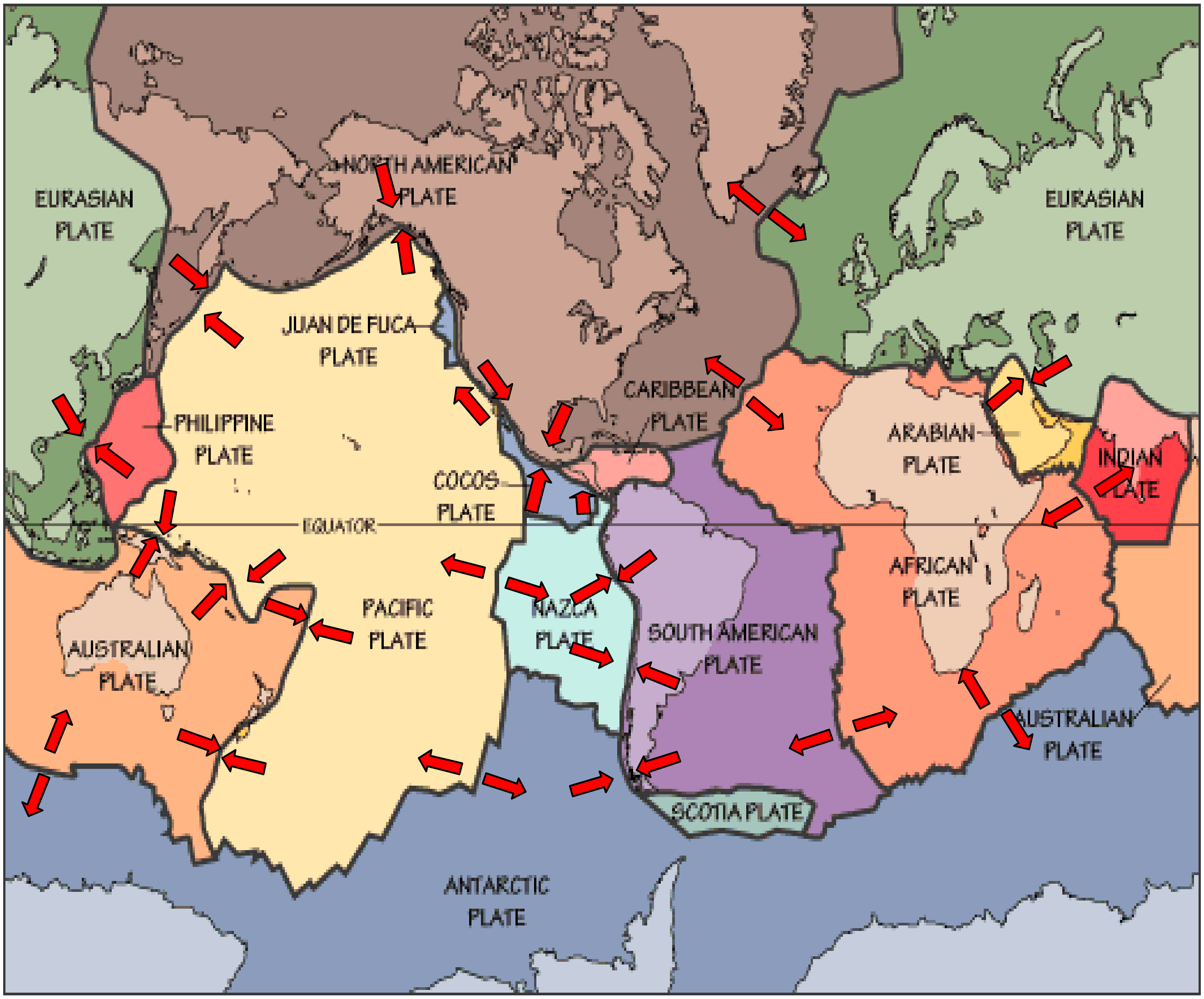
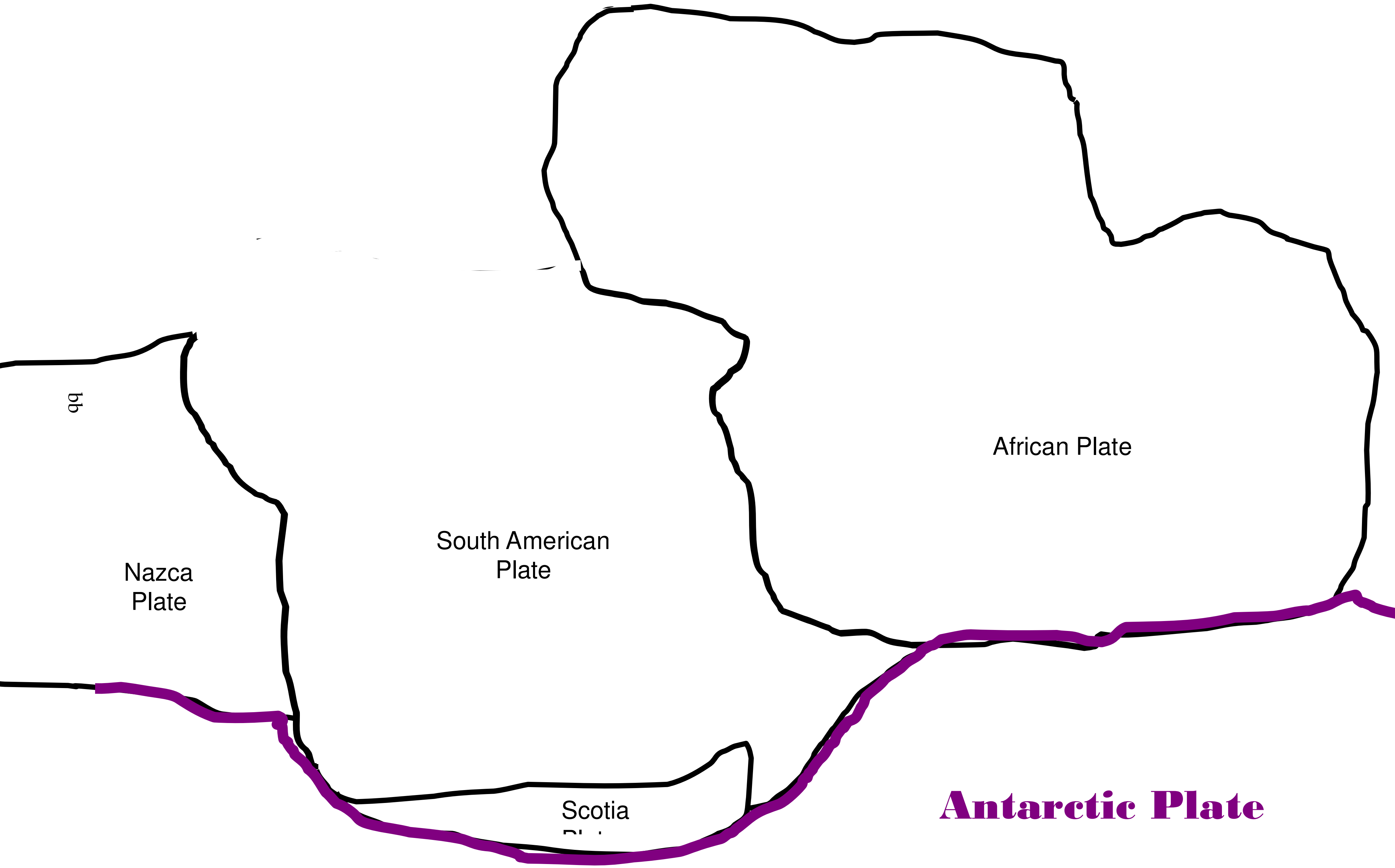


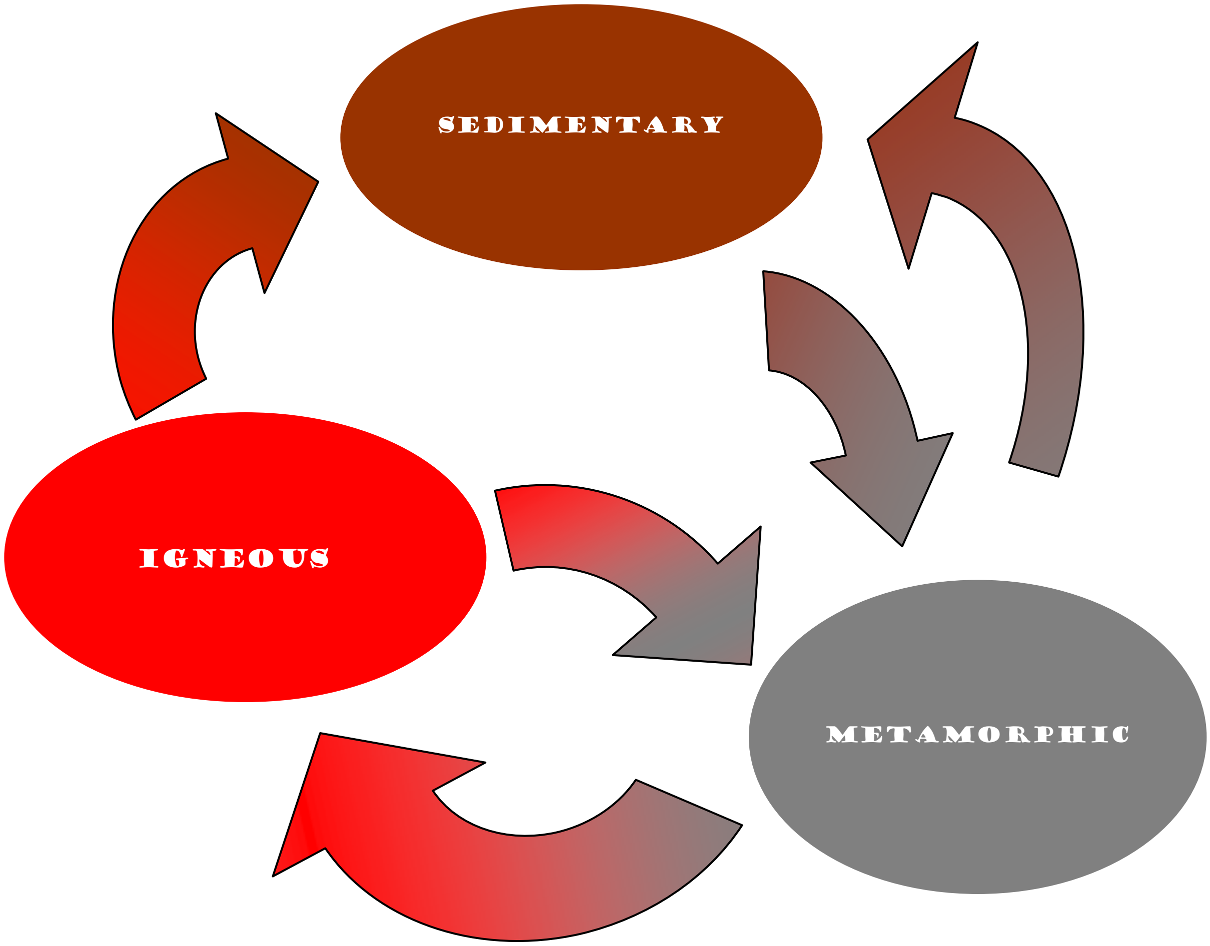
Plate map courtesy of the USGS (United States Geological Survey: http://pubs.usgs.gov/gip/dynamic/slabs.html
Arrows indicate direction of plate movement as collected from various tectonic maps available online and in research materials listed in the References section.

aa

Antarctic Plate Model



South American Plate Model (with Scotia Plate to the south)



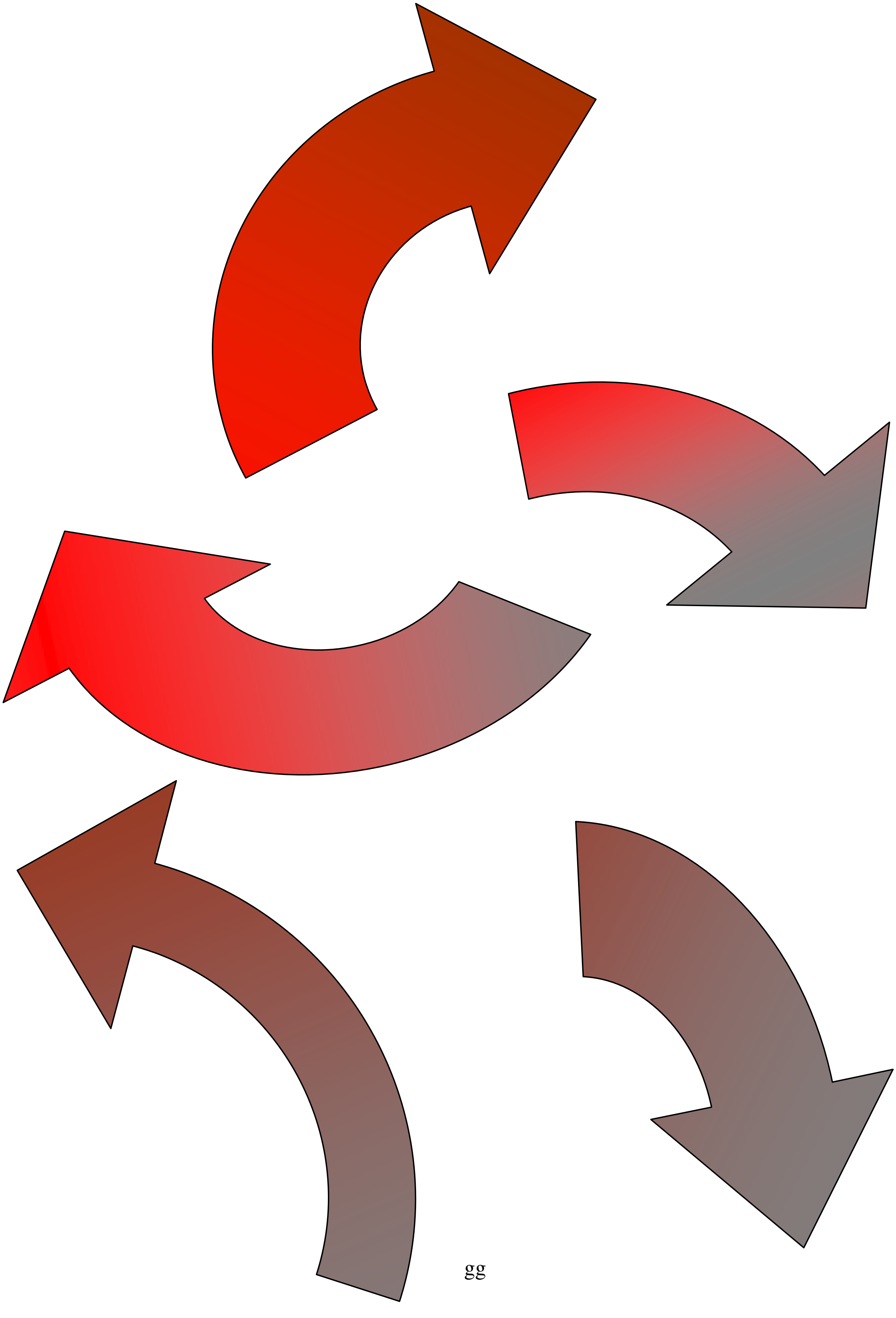
dd

SEDIMENTARY

IGNEOUS

ee

METAMORPHIC



gg

Sedimentary Rock Specimen Name: ______________________________ Type of Sedimentary Rock:______________ Location where found: _________________ Parent material: _______________________	Sedimentary Rock Specimen Name: ______________________________ Type of Sedimentary Rock:______________ Location where found: _________________ Parent material: _______________________
Sedimentary Rock Specimen Name: ______________________________ Type of Sedimentary Rock:______________ Location where found: _________________ Parent material: _______________________	Sedimentary Rock Specimen Name: ______________________________ Type of Sedimentary Rock:______________ Location where found: _________________ Parent material: _______________________
Sedimentary Rock Specimen Name: ______________________________ Type of Sedimentary Rock:______________ Location where found: _________________ Parent material: _______________________	Sedimentary Rock Specimen Name: ______________________________ Type of Sedimentary Rock:______________ Location where found: _________________ Parent material: _______________________
Sedimentary Rock Specimen Name: ______________________________ Type of Sedimentary Rock:______________ Location where found: _________________ Parent material: _______________________	Sedimentary Rock Specimen Name: ______________________________ Type of Sedimentary Rock:______________ Location where found: _________________ Parent material: _______________________

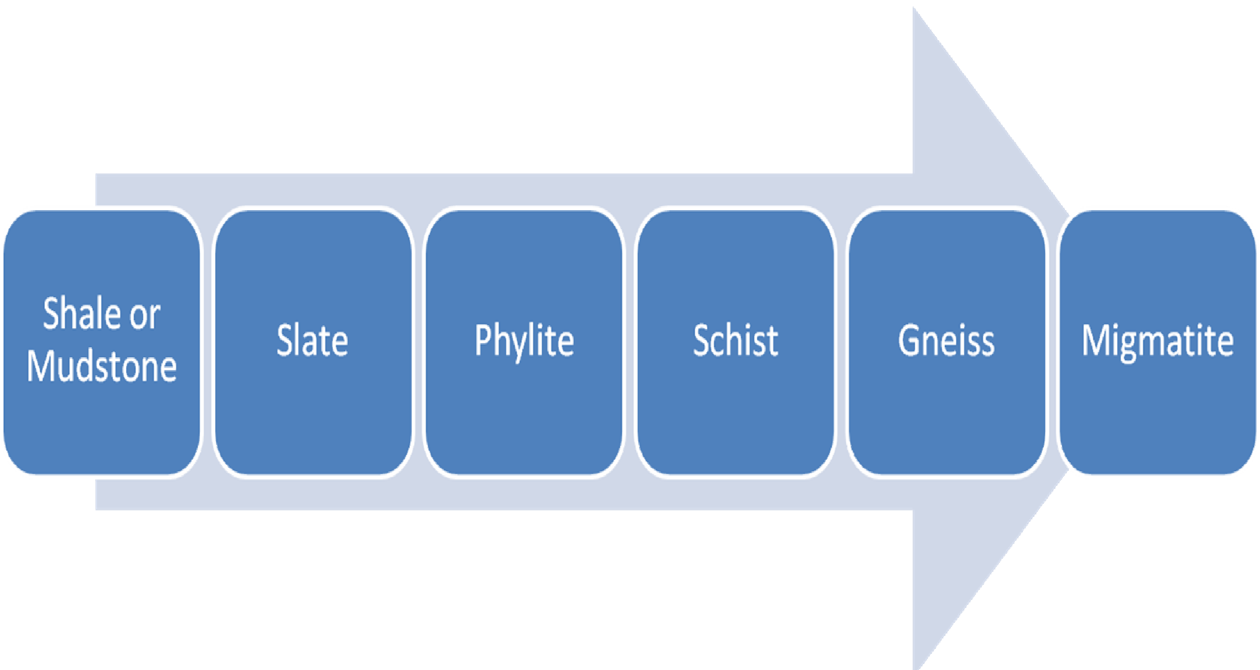
Metamorphic Rock Specimen Name: ____________________ Type:____________________ Location where found: __________ Parent material: ______________	Metamorphic Rock Specimen Name: ____________________ Type:____________________ Location where found: __________ Parent material: ______________
Metamorphic Rock Specimen Name: ____________________ Type:____________________ Location where found: __________ Parent material: ______________	Metamorphic Rock Specimen Name: ____________________ Type:____________________ Location where found: __________ Parent material: ______________
Metamorphic Rock Specimen Name: ____________________ Type:____________________ Location where found: __________ Parent material: ______________	Metamorphic Rock Specimen Name: ____________________ Type:____________________ Location where found: __________ Parent material: ______________
Metamorphic Rock Specimen Name: ____________________ Type:____________________ Location where found: __________ Parent material: ______________	Metamorphic Rock Specimen Name: ____________________ Type:____________________ Location where found: __________ Parent material: ______________

Igneous Rock Specimen Name: ______________________________ Type:_______________________________ Location where found: _________________ Notes on formation:	Igneous Rock Specimen Name: ______________________________ Type:_______________________________ Location where found: _________________ Notes on formation:
Igneous Rock Specimen Name: ______________________________ Type:_______________________________ Location where found: _________________ Notes on formation:	Igneous Rock Specimen Name: ______________________________ Type:_______________________________ Location where found: _________________ Notes on formation:
Igneous Rock Specimen Name: ______________________________ Type:_______________________________ Location where found: _________________ Notes on formation:	Igneous Rock Specimen Name: ______________________________ Type:_______________________________ Location where found: _________________ Notes on formation:
Igneous Rock Specimen Name: ______________________________ Type:_______________________________ Location where found: _________________ Notes on formation:	Igneous Rock Specimen Name: ______________________________ Type:_______________________________ Location where found: _________________ Notes on formation:

Mineral Specimen Name: ______________________________ Location where found: _________________ Color:______________________________ Hardness: __________________________ Crystal form:________________________	Mineral Specimen Name: ______________________________ Location where found: _________________ Color:______________________________ Hardness: __________________________ Crystal form:________________________
Mineral Specimen Name: ______________________________ Location where found: _________________ Color:______________________________ Hardness: __________________________ Crystal form:________________________	Mineral Specimen Name: ______________________________ Location where found: _________________ Color:______________________________ Hardness: __________________________ Crystal form:________________________
Mineral Specimen Name: ______________________________ Location where found: _________________ Color:______________________________ Hardness: __________________________ Crystal form:________________________	Mineral Specimen Name: ______________________________ Location where found: _________________ Color:______________________________ Hardness: __________________________ Crystal form:________________________
Mineral Specimen Name: ______________________________ Location where found: _________________ Color:______________________________ Hardness: __________________________ Crystal form:________________________	Mineral Specimen Name: ______________________________ Location where found: _________________ Color:______________________________ Hardness: __________________________ Crystal form:________________________

Degrees of Metamorphism

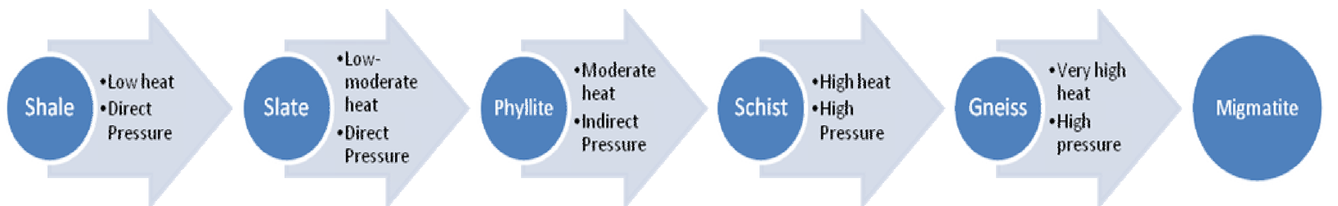
Foliated Metamorphic Rocks



Degrees of Metamorphism

Foliated Metamorphic Rocks

And the Conditions under Which They Develop



mm

Phyllite

Gneiss

Schist

Migmatite

Slate

Shale
or
Mudstone

Phyllite

Gneiss

Schist

Migmatite

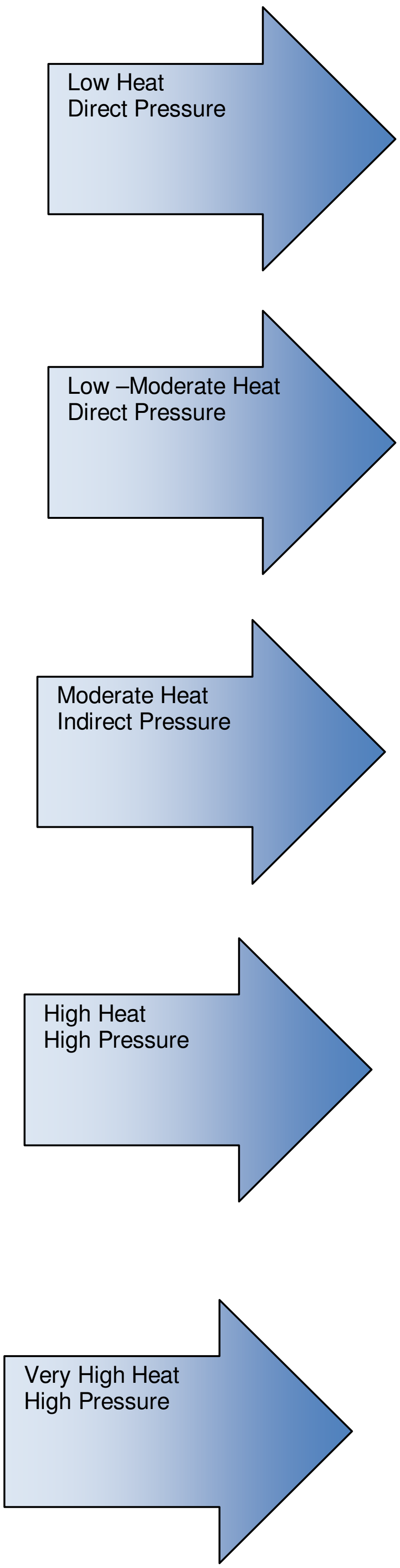
Slate

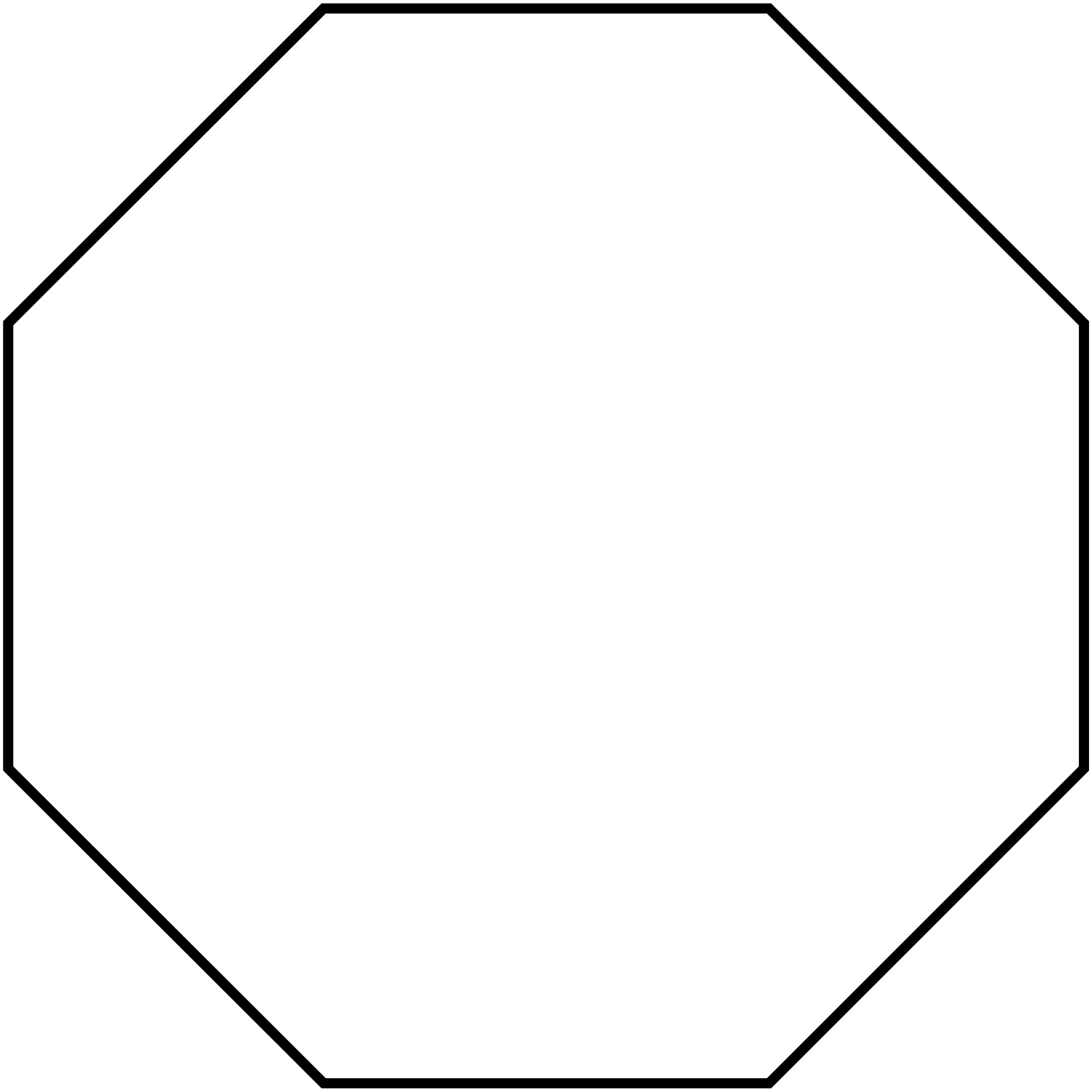
Shale
or
Mudstone

Degrees of Metamorphism

Foliated Metamorphic Rocks

And the Conditions under Which They Develop





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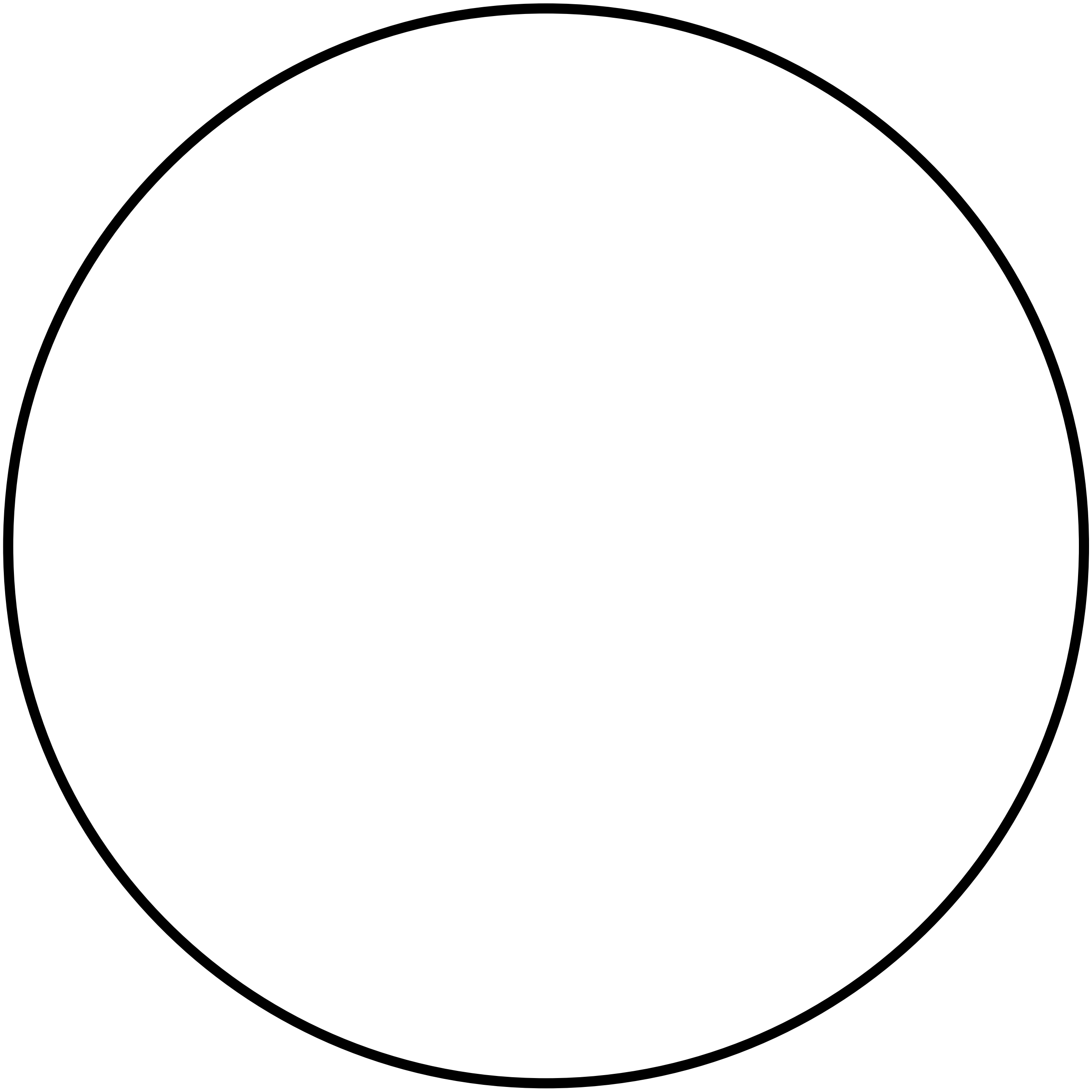

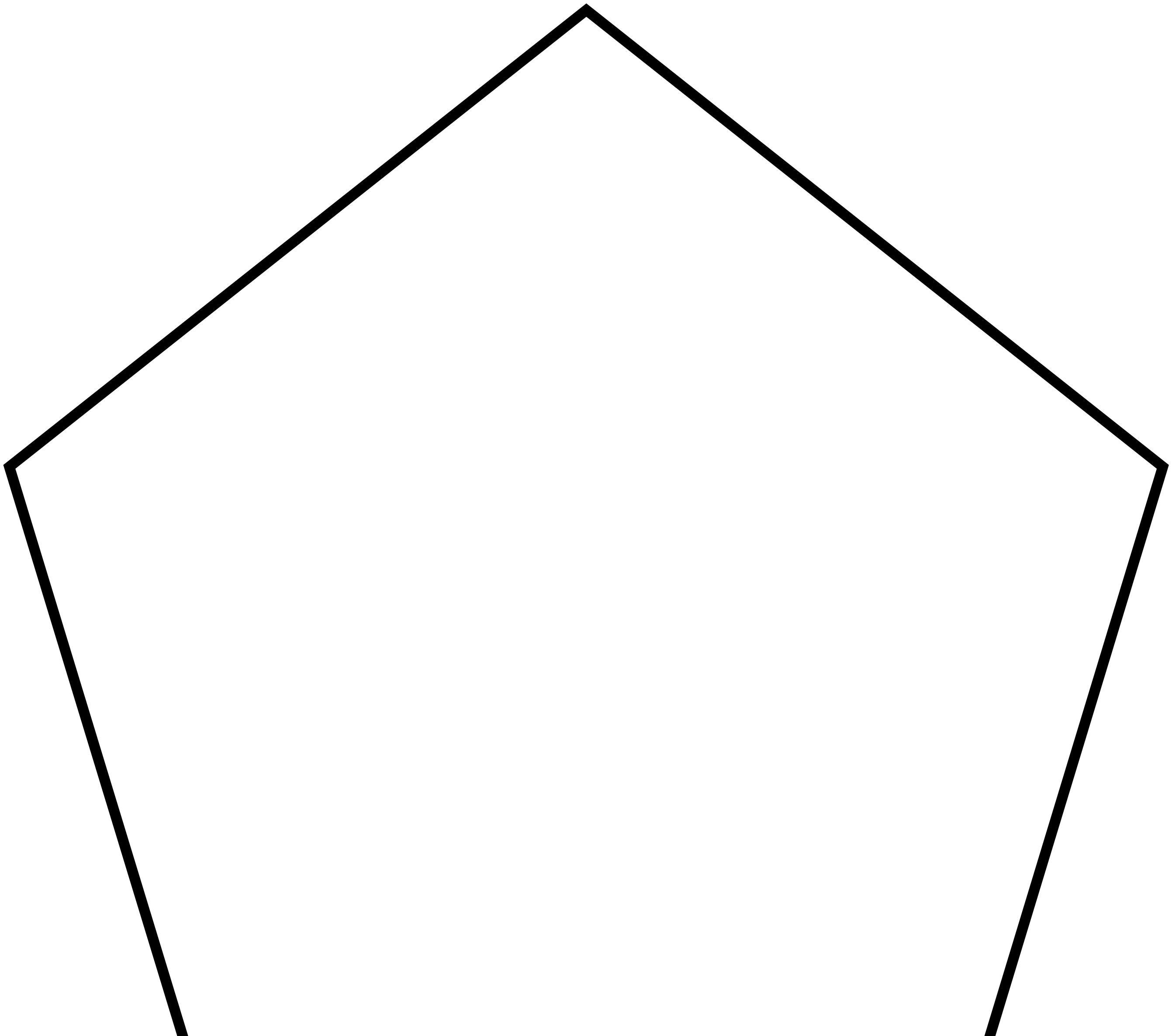

A List of Common Minerals and their Color Descriptions

Mineral	Color Description
apatite	green, blue, yellow, white
barite	colorless to varied colors
biotite mica	green, brown, black
calcite	colorless to white to pale colors
corundum	brown to gray, less often red, blue, brown, yellow
dolomite	buff, gray, white, pinkish
feldspar	salmon-pink, white, gray, green
fluorite	colorless, green, yellow, purple
galena	grayish black (shiny)
garnet	reddish brown, yellowish
graphite	dark gray to black
gypsum: selenite	clear, white, light gray
halite	clear to gray to red
hematite	steel gray, dull red
hornblende (amphibole)	black
kyanite	light blue to greenish blue to blue-gray
magnetite	gray-black
muscovite mica	colorless, silvery white, brownish silvery white
olivine	olive-green to yellow green
plagioclase	white to dark gray
pyrite	brassy-yellow, gold
quartz: amethyst	purple
quartz: rock quartz	clear to milky white
quartz: rose	pink
quartz: smokey	smoky-gray to black
sulfur	pale green to yellow
talc	green, gray, white
topaz	pale yellow, pale blue

Cards for Mineral Color/Streak Color Descriptions

green	black	gray
olive-green	grayish black (shiny)	brown
pale green	gray-black	buff
yellow-green	dark gray	reddish brown
blue-green	steel gray	dull red
blue	light gray	red
pale blue	blue-gray	purple
greenish blue	smoky-gray	light blue

pink	pinkish	salmon-pink
white	colorless	clear
milky white	silvery white	brownish silvery white
yellow	pale yellow	gold
brassy-yellow	yellowish	lemon-yellow

Who am I? Cards for Sedimentary Rocks

I am a sedimentary rock made of calcium carbonate or calcite. I am made up of the remains of mollusks, corals and other marine animals' shells. That makes me an organic or biogenic sedimentary rock. I make up about 10% of all sedimentary rocks on earth. I am a good stone for building and I am used in cement. Do you know who I am?	You can really tell I am a sedimentary rock because I am made of large sediments. I am made of lots of pebbles that have been rounded by fast-moving water. I may have once been a river bed. The tiny pebbles were cemented together as the water evaporated and other layers of rock settled on top, pushing me into shape and making me a solid rock. The pebbles can be all different types of rock. Who am I?
limestone	**conglomerate**
I am a sedimentary rock made of tiny grains of sand cemented together. The sand that makes me is mostly quartz. Silica, calcite and iron oxides are the most common cementing material. Sometimes there is a lot of iron in me that makes me a beautiful red color. Can you guess my name?	I am a sedimentary rock made of angular pebbles cemented together. Like my cousin, conglomerate, I was pressed into being by sediments that piled up on top of the angular rocks that I am made of. The rocks are cemented together by silica, calcite or iron oxide. Sometimes, when there is lots of iron, I have a red color. Do you know who I am?
sandstone	**breccia**

I am a common sedimentary rock. I am made of very fine particles of silt or clay. My particles are so fine that they can be carried by the wind or deposited by water in shallow seas. Once the particles are laid down, the weight of rocks or water on top cements them together and I an formed. Who am I?	I am made of the same materials as my cousin, limestone. The big difference between us is that you can actually see some of the ancient animal remains that made me. I get my name from all the fossils or impressions of fossils that are contained in me. These animals lived and died on the sea floor where their shells were cemented together to make me. Who am I?
shale	**Fossiliferous limestone**

I am an igneous rock. I come from magma made of basalt and andesite. The magma I am made of has lots of dissolved gases and I form when this magma reaches the surface and cools. The gases form burbles or holes as I cool. The walls around these holes often contain fragments of volcanic glass. I am usually colored dark brownish black or red. I am sometimes called cinder and was once used on running tracks. Who am I?	I am a dense volcanic glass. I am usually made of rhyolite that is rich in iron and magnesium. I form when the lava cools so quickly that no crystals can form. I fracture with very sharp edges, so I was a favorite of Stone Age people for making knives, arrowheads and other tools where sharp edges are important. Can you guess my name?
scoria	**obsidian**
I am a hard, black volcanic rock. I am the most common rock type in the earth's crust. Most of the ocean floor is made of me. I form when magma reaches the surface of the earth and flows out. I am made of very little silica, so I can flow quickly and volcanic gases escape easily without exploding. Do you know who I am?	I am an igneous rock that forms deep inside the earth. That makes me an intrusive igneous rock. I form when magma is pushed up close enough to the surface to cool, but not close enough to come to the surface. Because I cool very slowly, I form large crystals. I have a course grained texture made of many minerals. The different minerals give me beautiful colors of pink, black or gray. Who am I?
basalt	**granite**

I am a light-colored volcanic rock. Unlike my cousin, basalt, I am made of lots of silica. That makes me very thick or viscous. Gases do not escape from me easily, so I am formed in explosive eruptions. Pumice is often formed alongside me in these violent eruptions. I am made of minerals such as quartz, feldspar or biotite. Can you guess my name?	I am an extrusive igneous rock. I form in explosive eruptions. I am full of holes caused by expanding volcanic gases. I am made of volcanic glass and minerals. I can form in all types of magma: basalt, andesite, dacite and rhyolite. Most of the time I am so light weight that I can float in water. Do you know who I am?
rhyolite	**pumice**

I am made up of very tiny grains. You might need to use a magnifying glass to see them. Long ago I was volcanic ash or clay. Over millions of years, the pressure of rocks above me caused me to change forms. That is why I am called a metamorphic rock. You can easily split me into thin, flat plates. That makes me a foliated rock. I am very useful to humans. They use me for roof shingles, floor tiles, and the tops of pool tables. Who am I?	I am a metamorphic rock. I started out as igneous or sedimentary rock on the bottom of the sea. I can look a lot like schist, but instead of coarse grains, I have rows, or bands, of different colored minerals. That makes me a foliated rock. I was formed under so much heat and pressure that most of the minerals have recrystallized. You won't find much mica in my grains, but you may find quartz. Do you know who I am?
slate	**gneiss**
I am made up of large course grains. They are so big that you can see the grains without a magnifying glass. The grains are long and flat. You may see bits of the mineral Mica in the grains. They are flat and shiny. I am a metamorphic rock. That means I have changed forms over many millions of years. In fact, of all the metamorphic rocks, I have changed forms the most often. I may have started as mud, clay or igneous rock. Who am I?	I am a metamorphic rock that comes from metamorphosed limestone or dolomite. I can be almost any color including white, black, red and green. I am used as a building material for my strength and beauty. My crystals do not line up in rows or lines, so I am a non-foliated metamorphic rock. When my grain is very fine I am highly prized for creating sculptures. Can you guess my name?
schist	**marble**

I am a coarse-grained metamorphic rock. I began as sandstone. Heat and pressure forced the grains of sand together into solid stone. I have a uniform texture which means there are no thin layers and I cannot be split to make flat surfaces. That makes me a non-foliated metamorphic rock. I am very hard. I measure 7 on the Mohs Scale. I am usually white or grey and sometimes pink to red if iron is present. Who am I?	I am a fine grained metamorphic rock. I began as shale. I was squeezed and heated to become a new rock. I have changed more than slate but less than schist. I am primarily composed of quartz, mica, and chlorite. The crystals do not make lines and I cannot be split easily into flat plates. That makes me a non-foliated metamorphic rock. I have larger crystals than slate. Because of this I have a sheen or shine. Who am I?
quartzite	**phyllite**

Appendix C: Suggestions for Use of the Lessons and Materials

This e-book contains activities to help students of all ages enjoy knowing more about our earth.

Age Groups

The activities for the youngest children involve mostly sensorial experiences designed to encourage observation and discrimination of the diverse characteristics of rocks and minerals.

It is also possible to share many of the lessons that are specifically designed for older students with those who are under 6. These lessons would take the form of cultural lessons, observing photographs and talking about the natural phenomenon that is occurring whether it be lava flows, rainy weather or beautiful volcanic mountains.

Likewise, the activities rooted in observation are good work for older children, too. The teacher must watch her students to see what particular characteristics draw the students in and use those characteristics to focus the children's attention.

So, an attentive teacher may find that she or he may cross over between the sections and share freely between the various levels of lessons.

Sequence

The sequence that is presented in the book is a fairly linear progression, starting with some foundational concepts, moving into plate tectonics and then into examining the specific rock and mineral "species" by characteristics. However, a linear sequence is not necessarily the optimal way to progress. Children may bring in a rock that will launch a study into identification, so the teacher may choose to jump in with the rock cycle and the types of rocks.

Another possibility would be to focus on weather and weathering, then lead into a study of sedimentary rocks. Likewise, a study of volcanoes could branch out into igneous rocks, or it could move toward plate tectonics. The possibilities are endless.

Preparation and Classroom Set-up

Most of the follow-up activities are designed for independent choice once the lesson has been given. With this in mind, teachers are encouraged to determine which materials they will need for a month-long study and prepare all of them prior to beginning. The materials may be kept inboxes or baskets on the shelf in the sequence that will be presented. With this sort of set-up, the children will be encouraged to keep moving forward in their studies as they see the new items on the shelf.

We would love to hear from you about your experiences with Getting to Know Rocks and Minerals. If you have questions or comments for improvement, please don't hesitate to let us know those as well. You can contact us at claudiamann "at" fossilicious.com or dougmann "at" fossilicious.com.

Appendix D: Additional Resources

Earth Science (General)	
Layers of the earth	http://library.thinkquest.org/28327/html/universe/solar_system/planets/earth/interior/layers_of_earth.html From Think quest…a thorough investigation of the subject
Weather	http://www.econet.org.uk/weather/whatis.html
Volcanoes	http://volcano.oregonstate.edu/
	http://hvo.wr.usgs.gov/ Hawaii Volcano National Park site
Plate Tectonics	http://go.owu.edu/~khfryer/mog/geology/page6.html Dr. Karen Fryer, Professor of Geology, Ohio Wesleyan University
	http://www.nature.nps.gov/geology/usgsnps/project/home.html This USGS site has user-friendly graphics and explanations as well as many links to increasingly complex maps and articles.
	http://vulcan.wr.usgs.gov/Photo/framework.html This is the USGS Cascades Volcano Observatory site. It has many photos of different types of volcanoes.
Rocks	
Metamorphic Rock	http://facweb.bhc.edu/academics/science/harwoodr/GEOL101/labs/metamorf/ *Metamorphic Rock Identification Lab by Richard Harwood, Black Hawk College,*
	http://csmres.jmu.edu/geollab/Fichter/MetaRx/index.html *Metamorphic Rock site with info designed for elementary School teachers; Lynn S. Fichter © 2000 ; (fichtels@jmu.edu) Department of Geology and Environmental Science; James Madison University, Harrisonburg, Virginia 22807*
Minerals	http://mineral.galleries.com/Minerals/By_Name.htm
Crystals	www.science**kids**athome.com/science_topics/what_are_**crystals**.html
	www.nationalgeographic.com/ng**kids**/trythis/tryfun1.html
	http://chemistry.about.com/od/crystalsforkids/Crystal_Projects_for_Kids.htm