Physical Science 110B
Lab Manual

by

Mary G. Lusk

with
Barry R. Bickmore
and Melissa Schlegel

Brigham Young University
Department of Geology

Draft 3.0
January 2008

PS 110B Lab/PS 111B Syllabus
Earth Science for Pre-Service Elementary Teachers

Instructor: Dr. Barry R. Bickmore
Phone: 2-4680
Office: S-321 ESC
Office Hours: TTh 3-5

Lecture Classroom: C-215 or C-285 ESC
Lab Classroom: N 111 ESC
Text: *Physical Science 110B Lab Manual* version 3 by Mary Lusk

Learning Outcomes

1. Students should be able to explain the nature of science accurately.
2. Students should be able to identify common rocks and minerals, and explain how they formed.
3. Students should become familiar with Utah Core Curriculum science standards for K-6 and experience a small taste of what it is like to work with real elementary school children.

Requirements

1. A number of hands-on activities will be given during the lab period to be completed during that period.
2. Groups of students will create a Mini-Lesson to be presented near the end of the semester. The presentations will be given during a REQUIRED field trip to Farrer Elementary School, 600 East 100 North, Provo. Each lab section will be assigned a set of science education standards for the Utah state core curriculum. The work of teaching the principles involved will be divided among the groups in the lab. Lesson plans for these Mini-Lessons will be turned in for a grade, and "dry run" of these presentations will be held in the lab sections before the final presentations, so that constructive feedback can be given.

Grading

The lab portion of PS 110B, excluding the final project, accounts for 20% of the final grade. The final project is worth 10% of the final grade. Since PS 111B students are only enrolled in the lab portion of the class, the lab activities and final projects account for their entire grade. Following are breakdowns of the lab-based assignments and their weights in terms of the final grade for PS 110B and PS 111B students.

PS 110B

Participation	3%
Attitude	2%
Rock/Mineral ID Final	15%

PS 111B

Participation	15%
Attitude	5%
Rock/Mineral ID Final	50%
Mini-Lesson	20%
NOS Quiz	5%
NOS Writing	5%

93-100% = A
90-92% = A-
87-89% = B+
83-86% = B
80-82% = B-
77-79% = C+
73-76% = C
70-72% = C-
67-69% = D+
63-66% = D
60-62% = D-

Participation Grade

Each week in lab you have a possible 10 points for the participation grade. 3 points are for coming to class and staying the whole time. 4 points are for reading the assigned chapter in the lab manual BEFORE coming to the lab. 3 points are for doing the questions at the end of each lab. Note: If your TA does not think you are putting forth a legitimate effort in answering these questions, you will not get the points. Similarly, if you do not answer the questions in FULL SENTENCES, you will not get the points. Part of this class is learning how to verbalize science concepts, so one-word answers just won't cut it.

Attitude Grade

Some people just aren't "science people," and that is fine for other introductory science classes. Here the students are preparing to teach elementary school classes, and the attitude you exhibit about teaching science will carry over to many of your students. Therefore, if science is not your favorite subject, then think about how the education of children is your favorite subject, and *do what it takes* to prepare yourself for your profession. Elementary school teachers do not have the luxury of neglecting certain subjects, and the TA's will not put up with a bad attitude in the lab, because the lab is where you will be practicing to become teachers. 10 points per week of lab will be given for attitude, and you will not get these points if you do not show up to lab.

Rock and Mineral Identification Final

Throughout the semester, but especially near the beginning, you will be studying rock and mineral identification in your lab. *This is very important*. When you start studying rocks and minerals in your elementary school classrooms, what do you suppose will be the first questions the kids ask? They will invariably bring rocks into class and ask you what they are. It would be nice if your answer were something other than, "a really cool rock!" Near the end of the class you will be given a rock and mineral identification test, where you will be asked to 1) identify the rock and mineral specimens, tell which class each rock specimen belongs to—igneous (plutonic or volcanic,) metamorphic, or sedimentary (detrital or chemical.) You will also have to 2) describe a diagnostic feature you used to determine the identity of each mineral specimen, and 3) tell a basic story about how each rock specimen came to be.

Extra Credit!!!

Up to 2% of the final grade for PS 110B (and 5% of the final grade for PS 111B) in extra credit can be earned by doing a particularly polished and creative class project presentation. Experience has shown that some PS 110B students may struggle a bit with earth science, while others are quite gifted in this area. However, almost all PS 110B students are *fantastic* at teaching science to small children. If I see that you are going the extra mile to make a difference in the lives of the students at Joaquin Elementary, I will reward you for that. On the other hand, you had better not show up with some half-baked presentation that you made up the night before, because your grade will be hurting.

Your TA will take you to Rock Canyon for a field trip. Participation will get you another 2% extra credit.

Policies

Late Work

Lab work is harder to make up than a regular homework assignment. If your TA is willing, I allow make-up work in lab, but this is completely up to your TA. In most cases I discourage allowing make-up work unless the student has arranged something BEFORE missing class. For instance, an easy way to make up a lab session might be to go to another section, but you will have to arrange this with the two TA's involved.

Preventing Sexual Harassment

BYU's policy against sexual harassment extends not only to employees of the university but to students as well. If you encounter sexual harassment, gender-based discrimination, or other inappropriate behavior, please talk to your professor, contact the Equal Employment Office at 422-5895 or 367-5689, or contact the Honor Code Office at 422-2847.

Students With Disabilities

BYU is committed to providing reasonable accommodation to qualified persons with disabilities. If you have any disability that may adversely affect your success in this course, please contact the University Accessibility Center at 422-2767. Services deemed appropriate will be coordinated with the student and instructor by that office.

Children in the Classroom

The study of Geology requires a degree of concentration and focus that is exceptional. Having small children in class is often a distraction that degrades the educational experience for the whole class. Please make other arrangements for child care rather than bringing children to class with you. If there are extenuating circumstances, please talk with your instructor in advance.

Farrer Elementary Mini-Lessons

Learning Outcomes

After completing this project, students should be able to do the following.

- Plan a short lesson to teach a science principle. The lesson should be accurate, targeted, interactive, and connected to reality.
- Carry out that plan.

Explanation

So you want to teach elementary school. Well, for most of you, this class is going to give you your first, tiny taste. Your lab section has been assigned a certain set of physical science standards from the Utah Core Curriculum for grades 1-6. You will be divided into groups (about 8-9 per section) and assigned a standard, or part of a standard, to teach. You will come up with a plan for a short, 5-minute lesson, which will be critiqued by your TA and your peers. You will then revise your lesson plan and gather your materials, after which your TA and peers will critique a "dress rehearsal" of your mini-lesson. Finally, you will be assigned a time to show up to Farrer Elementary and deliver your mini-lesson to real kids, over and over for 1-2 hours.

You should be aware that it takes more than 5 minutes to teach kids about these things, and they are already learning them in school. Also, it is best to teach science through inquiry as much as possible, and you will learn how to do that in ElEd 363. Therefore, with this project you really will only be getting a tiny taste of science teaching, and will just be helping the kids review the materials they are trying to learn.

Nevertheless, this assignment also is meant to perform other important functions. You will hopefully learn what it means to make a science lesson 1) accurate, 2) targeted, 3) interactive, and 4) connected to reality (see below.) You will also be setting an example for the children. Farrer Elementary serves a VERY underprivileged part of Provo, and many of the kids don't really know anyone who has gone to college. (Just to give you an idea, about 75% of the kids qualify for free or reduced-price school lunch, 65% of the kids speak English as a second language (if at all,) and there is about 65% turnover in the school population each year. (The principal tells me that many of the kids only stay for a few weeks because, for example, their mothers are on the run from abusive husbands.) The administrators and teachers at Farrer love for us to come do these mini-lessons—not to replace regular science instruction—but to reinforce it and let the kids meet some young adults who are trying to make a good future for themselves.

For logistics and various details, you should visit the website for the project, which is linked from the course Blackboard site. Here are some brief instructions, however.

Instructions

Picking a Topic

See the next section of this document to find the topics your lab section is assigned. Your TA has ultimate authority over who gets assigned different topics within the set that is assigned to your section, but he or she may allow you to argue your case for being assigned the topic of your choice. Come up with brief plans for your top choices!

Note that the topics are divided into different “standards” from the Core Curriculum, but some of these can cover quite a bit of information. Since your mini-lessons are only 5 minutes, it might only be feasible to tackle part of a standard, and another group could take on another part.

Organizing Group Work

Group work can be frustrating unless care is taken in its design. In the pages after these instructions you will find a worksheet entitled, “Collaborative Work Plan” to help you design your work so that everyone pulls their share of the load.

Creating a Lesson Plan

Your lesson plan has two main purposes. First, it is meant to help you clarify what you will teach and how you will teach it. Second, it is meant to be shared with others. Teachers are notorious for sharing lesson plans, and for good reason. Have you ever considered how hard it is to come up with 6 hours of education activities, 5 days per week? (Perhaps you should even see if other groups in your section might like a copy of your lesson plan to keep.) In keeping with these purposes, here are detailed instructions for the different sections you need to include in your lesson plan. It is important that you construct these sections IN ORDER.

Concept Summary. Write a clear, concise summary of the concept you mean to teach (1-2 paragraphs.) You should refrain, however, from mentioning how you will teach it, or even that you are going to teach it at all. You are just explaining the concept, in other words. Look on the project website for some good and bad examples.

The main reason I make you do this is that I want your TA to catch it early if you don’t really understand the concept you are undertaking to teach. Don’t dismiss this—I’ve seen it happen many times. And even many elementary school science textbooks explain some concepts incorrectly.

Misconceptions about science are so pervasive, in fact, that I require you to research those related to your topic before you craft your lesson plan. It’s easy. Suppose you wanted to teach about the water cycle, for instance. If you were to type “water cycle misconceptions” into the Google search engine, one of the hits would be a page at Weber State University that lists the following misconceptions. “Students believe groundwater… flows through underground rivers or occurs in subterranean lakes.” “Students believe groundwater and surface supplies are two totally separate systems.” “Students believe only water from oceans and lakes evaporates and not from streams and other sources.” “Students believe the water cycle involves freezing and melting of water.” “Students believe rain falls out of the sky when the clouds evaporate.” Obviously all of these couldn’t be addressed in a single 5-minute lesson, but if you craft your lesson with these common misconceptions in mind, you may be able to address one or two, and you will certainly be more careful about how you explain yourself!

In short, your goal is to write an *accurate* summary of the concept you mean to teach, that is *targeted* to address at least one common misconception. (See the Learning Outcomes above.)

Learning Outcomes. List exactly what you expect your students to be able to DO after they move away from your table. Notice that I didn't say to list what they should *understand*. Why? Because you can't measure understanding, but you can measure whether students can *do* particular things. If you were teaching a lesson about clouds and precipitation, for example, a possible learning outcome might be for your students to be able to explain that clouds are made of tiny liquid water droplets, rather than water vapor. Of course, if you *say* this is your learning outcome, then you are obliged to find out whether this was, in fact, the outcome of your lesson. See below for ideas on how to accomplish this.

Assessment. Ask yourself, "What would convince me that my students have obtained the stated learning outcomes?" Come up with something that is feasible for you to do in a short amount of time. You could, for instance, design a short game or quiz for your students to take near the end of your 5 minutes. Make sure to leave time to correct them if they get it wrong.

Activity. Now that you know what would convince you of your students' success, ask yourself, "What kind of activity would help them succeed in my assessment?" Feel free to swipe your activity off the Internet, but make sure to modify it if it doesn't exactly meet your needs. Following are a few things to look out for.

Is your activity as *interactive* as possible? You do not, for example, want to stand in front of the kids and yack at them the whole time. And while demonstrations are nice, they can still be designed to require only passive involvement for the students. Instead of just doing a demonstration, then, why not have your students predict what will happen in the demonstration before you do it? If they turn out to be wrong, they will be all ears when you explain the results to them.

If you give your students *abstractions* or *analogies*, do you clearly *connect them back to reality*? Sometimes my students get so into making little cartoonish pictures (which can be useful abstractions,) and making clever analogies using household products (which can be very powerful,) they forget to connect them back to reality. A drawing of the structure of a volcano is great, but wouldn't it be better if it were presented alongside a photo of an actual volcano? Analogies and abstractions can be very useful, but there are always differences between them and the real thing. If they aren't connected with and compared to reality, your students might come away with some weird misconceptions that you had no intention of teaching!

Materials Needed. Remember that you want to keep every lesson plan you ever make (even dinky ones like this,) and share them with others! Any teacher should be able to read your lesson plan and know exactly how to carry it out.

Critiquing Lesson Plans

One lab period will be set aside to critique one another's lesson plans. Do not show up without a complete, neatly typed draft, because it would be irresponsible, and disrespectful to your classmates. In addition, your TA will dock 25% off your overall project grade if you do that. As you look them over, ask these questions.

- Is the concept stated clearly and correctly?
- Is at least one common misconception addressed?
- Are the learning objectives focused narrowly enough—i.e., can they be accomplished in some fashion within 5 minutes?

- Will the assessment actually indicate whether the learning outcomes have been reached? (It's very easy to make an assessment that doesn't really test what you care about.)
- Is the activity designed specifically to help the students succeed at the assessment?
- Is the activity interactive? Could it easily be more interactive?
- Are abstractions and analogies connected back to reality?

Critiquing Presentations

Another two lab periods will be set aside for "dress rehearsals" of the mini-lessons, you will critique each others' performances. I know it isn't easy to criticize your friends' work, but please give them credit for being adults, and help them improve! By the same token, don't show up to the dress rehearsal without being completely prepared to give your mini-lesson EXACTLY as you are planning to do it at the elementary school. That would be rude and inconsiderate. And your TA would dock another 25% off your total project grade.

As you watch the presentations, ask yourself the same questions you did when critiquing the lesson plans, and also the following.

- Do the presenters go out with the "children," or just hide behind their table?
- If one partner is leading the discussion, does at least one of the others go out with the "children" to help them focus their attention? (Some of them are a little squirrelly.)
- DOES IT TAKE 5 MINUTES OR LESS?

COLLABORATIVE WORK PLAN

Name	Phone	email

Communication:
Decide as a group how you will communicate with each other. Think about some of these possible questions and any other specific situations:

- Will you use email?
- Will you use the phone?
- When emailing, will you copy the entire group or just the person you are communicating with?
- How quickly to the communication should you respond?

Decide how often you will communicate:

- Daily?
- After major tasks?
- Will you have weekly face-to-face meetings?

Roles:
While everyone in the group is EXPECTED to participate in the research, writing, and production of the mini-lesson, you should decide as a group how you will handle the functions of follow-up on task assignments, final review of the project, and organizing of the communication (there may be other roles that your project will need and your group should think about these and how your group will handle them).

- Will one person be checking to see that all tasks are being completed on time?
- How will the group do a final review of the lesson?
- Will you rotate the responsibility of scheduling group meetings?

Performance:
It is crucial that all members of the group attend the labs and all group meetings. How the group will work should be decided upon at this point.

- How can everyone be involved in content research?
- How can you divide the production tasks up while still including all in the development?
- How will you hold all members responsible for attendance and task completion?

Rubric for Lesson Plans

Category	Points
Clear and correct problem statement. (20 points)	
Common misconception addressed. (10 points)	
Appropriately focused learning objectives. (10 points)	
Assessment designed to test whether students meet objectives. (20 points)	
Activity designed to help students succeed at assessment. (20 points)	
Activity as interactive as possible. (10 points)	
Abstractions and analogies connected to reality. (10 points)	
Total (100 pts. possible)	

Rubric for Presentations

Dear Farrer teachers,

My students would much rather have you critique their presentations than me! In other words, they want feedback from real elementary school teachers who are in the trenches. Please fill out the following rubrics for the presentations given to the grade level of your class, and hand them back to me. I will use them to assign grades.

Barry Bickmore

GROUP #________

1. **Was the presentation accurate?**

not very		somewhat		very
1	2	3	4	5

2. **Did the presentation address a common misconception about the topic?**

not really		somewhat		absolutely
1	2	3	4	5

3. **Did the presenters involve the students rather than just talking at them?**

not really		somewhat		absolutely
1	2	3	4	5

4. **How would you rate the overall performance, including intangibles not mentioned above?**

Poor	Good for a Beginner		Polished and Professional
0	1	2	3

If you would like to make any further comments, please use the back of this sheet.

Farrer Project—
Topic Assignments

Look up your section number in the class, then find the list of curriculum standards assigned to your class in the following pages. Your group will choose some items from the list that you think you can teach effectively in 5 minutes. (Go for quality over quantity.) Your TA will ultimately decide who gets to teach what—everyone should be covering something different.

Section 1--First Grade

Standard 3

Students will develop an understanding of their environment.

Objective 2

Investigate water and interactions with water.

a. Observe and measure characteristics of water as a solid and liquid.
b. Compare objects that float and sink in water.
c. Measure and predict the motion of objects in water.
d. Describe how plants and people need, use, and receive water.

Objective 3

Demonstrate how symbols and models are used to represent features of the environment.

a. Use map skills to identify features of the neighborhood and community.
b. Create representations that show size relationships among objects of the home, classroom, school, or playground.
c. Identify map and globe symbols (e.g., cardinal directions, compass rose, mountains, rivers, lakes).
d. Locate continents and oceans on a map or globe (i.e., North America, Antarctica, Australia, Pacific Ocean, Atlantic Ocean).

Ideas for connections to earth science:

1. frost wedging—water expands when it freezes
2. icebergs—ice floats because it is expanded. Maybe compare to something else that does not float when it melts?
3. glaciers—how they affect the landscape
4. magma/lava vs. igneous rock—lava can flow out of a volcano and cover the land, but when it cools it turns to solid rock
5. maps—help students understand the basic concept of maps, and show a couple different kinds of maps that are used for earth science (topographic maps where there are actually little mountains rather than altitude lines, geologic maps, etc.)
6. maps of the world—if the world is round, how can you draw it on a flat piece of paper? Show globes vs. flat maps of the world.
7. Lesson plans for teaching about maps, etc., can be found at: http://interactive2.usgs.gov/learningweb/teachers/lesson_plans.htm

More resources at:
http://www.teach-nology.com/teachers/lesson_plans/science/earth_sciences/

Section 2: Second Grade

Standard 3

Students will develop an understanding of their environment.

Objective 2

Observe and describe weather.

a. Observe and describe patterns of change in weather.
b. Measure, record, graph, and report changes in local weather.
c. Describe how weather affects people and animals.
d. Draw pictures and create dances and sounds that represent weather features (e.g., clouds, storms, snowfall).

Objective 3

Investigate the properties and uses of rocks.

a. Describe rocks in terms of the parts that make up the rocks.
b. Sort rocks based upon color, hardness, texture, layering, and particle size.
c. Identify how the properties of rocks determine how people use them.
d. Create artworks using rocks and rock products.

Objective 4

Demonstrate how symbols and models are used to represent features of the environment.

a. Identify and use information on a map or globe (i.e., map key or legend, compass rose, physical features, continents, oceans).
b. Use an atlas and globe to locate information.
c. Locate continents and oceans on a map or globe (i.e., North America, Antarctica, Australia, Africa, Pacific Ocean, Atlantic Ocean).

Ideas for connections to earth science:

1. different kinds of precipitation
2. how do floods and mudslides happen?
3. Lesson plans for teaching about maps, etc., can be found at: http://interactive2.usgs.gov/learningweb/teachers/lesson_plans.htm
4. maps—help students understand the basic concept of maps, and show a couple different kinds of maps that are used for earth science (topographic maps where there are actually little mountains rather than altitude lines, geologic maps, etc.)
5. maps of the world—if the world is round, how can you draw it on a flat piece of paper? Show globes vs. flat maps of the world.
6. Chapters 2 and 6 of *Earth Science for Every Kid* have lots of ideas for teaching about rocks and minerals and weather.

More resources at:
http://www.teach-nology.com/teachers/lesson_plans/science/earth_sciences/

Section 3—Third Grade

Standard I:

Students will understand that the shape of Earth and the moon are spherical and that Earth rotates on its axis to produce the appearance of the sun and moon moving through the sky.

Objective 1:

Describe the appearance of Earth and the moon.

a. Describe the shape of Earth and the moon as spherical.
b. Explain that the sun is the source of light that lights the moon.
c. List the differences in the physical appearance of Earth and the moon as viewed from space.

Science language:

model
orbit
sphere
moon
axis
rotation revolution
appearance

Objective 2:

Describe the movement of Earth and the moon and the apparent movement of other bodies through the sky.

a. Describe the motions of Earth (i.e., the rotation [spinning] of Earth on its axis, the revolution [orbit] of Earth around the sun).
b. Use a chart to show that the moon orbits Earth approximately every 28 days.
c. Use a model of Earth to demonstrate that Earth rotates on its axis once every 24 hours to produce the night and day cycle.
d. Use a model to demonstrate why it seems to a person on Earth that the sun, planets, and stars appear to move across the sky.

Science Benchmark

Forces cause changes in the speed or direction of the motion of an object. The greater the force placed on an object, the greater the change in motion. The more massive an object is, the less effect a given force will have upon the motion of the object. Earth's gravity pulls objects toward it without touching them.

Standard III:

Students will understand the relationship between the force applied to an object and resulting motion of the object.

Objective 1:

Demonstrate how forces cause changes in speed or direction of objects.

a. Show that objects at rest will not move unless a force is applied to them.
b. Compare the forces of pushing and pulling.
c. Investigate how forces applied through simple machines affect the direction and/or amount of resulting force.

Objective 2:
Demonstrate that the greater the force applied to an object, the greater the change in speed or direction of the object.

a. Predict and observe what happens when a force is applied to an object (e.g., wind, flowing water).
b. Compare and chart the relative effects of a force of the same strength on objects of different weight (e.g., the breeze from a fan will move a piece of paper but may not move a piece of cardboard).
c. Compare the relative effects of forces of different strengths on an object (e.g., strong wind affects an object differently than a breeze).
d. Conduct a simple investigation to show what happens when objects of various weights collide with one another (e.g., marbles, balls).
e. Show how these concepts apply to various activities (e.g., batting a ball, kicking a ball, hitting a golf ball with a golf club) in terms of force, motion, speed, direction, and distance (e.g. slow, fast, hit hard, hit soft).

Science Benchmark

Forces cause changes in the speed or direction of the motion of an object. The greater the force placed on an object, the greater the change in motion. The more massive an object is, the less effect a given force will have upon the motion of the object. Earth's gravity pulls objects toward it without touching them.

Standard IV:

Students will understand that objects near Earth are pulled toward Earth by gravity.

Objective 1:
Demonstrate that gravity is a force.

a. Demonstrate that a force is required to overcome gravity.
b. Use measurement to demonstrate that heavier objects require more force than lighter ones to overcome gravity.

Objective 2:
Describe the effects of gravity on the motion of an object.

a. Compare how the motion of an object rolling up or down a hill changes with the incline of the hill.
b. Observe, record, and compare the effect of gravity on several objects in motion (e.g., a thrown ball and a dropped ball falling to Earth).
c. Pose questions about gravity and forces.

Science language:

distance
force
gravity
weight
motion
speed
direction
simple machine

Science Benchmark

Light is produced by the sun and observed on Earth. Living organisms use heat and light from the sun. Heat is also produced from motion when one thing rubs against another. Things that give off heat often give off light. While operating, mechanical and electrical machines produce heat and/or light.

Standard V:

Students will understand that the sun is the main source of heat and light for things living on Earth. They will also understand that the motion of rubbing objects together may produce heat.

Objective 1:

Provide evidence showing that the sun is the source of heat and light for Earth.

a. Compare temperatures in sunny and shady places.
b. Observe and report how sunlight affects plant growth.
c. Provide examples of how sunlight affects people and animals by providing heat and light.
d. Identify and discuss as a class some misconceptions about heat sources (e.g., clothes do not produce heat, ice cubes do not give off cold).

Objective 2:

Demonstrate that mechanical and electrical machines produce heat and sometimes light.

a. Identify and classify mechanical and electrical sources of heat.
b. List examples of mechanical or electrical devices that produce light.
c. Predict, measure, and graph the temperature changes produced by a variety of mechanical machines and electrical devices while they are operating.

Objective 3:

Demonstrate that heat may be produced when objects are rubbed against one another.

a. Identify several examples of how rubbing one object against another produces heat.
b. Compare relative differences in the amount of heat given off or force required to move an object over lubricated/non–lubricated surfaces and smooth/rough surfaces (e.g., waterslide with and without water, hands rubbing together with and without lotion).

Ideas for connections to earth science:

a. several demos regarding the shape of the earth, how the earth and moon move, etc., can be found in ch. 1 of *Earth Science for Every Kid.*
b. layers of the earth
c. how did people figure out that the earth was round?
d. how would the earth look to you, if you were standing on the sun (assuming your eyeballs were not incinerated)?
e. gravity—why does the moon keep going around the earth? Why does the earth keep going around the sun? Use a ball-and-string demo to show that some force must be pulling them inward, or they would fly away.
f. gravity—what is gravity?
g. landslides and gravity

More resources at:
http://www.teach-nology.com/teachers/lesson_plans/science/earth_sciences/

Section 4—Fourth Grade

Science Benchmark

Matter on Earth cycles from one form to another. The cycling of matter on Earth requires energy. The cycling of water is an example of this process. The sun is the source of energy for the water cycle. Water changes state as it cycles between the atmosphere, land, and bodies of water on Earth.

Standard I:

Students will understand that water changes state as it moves through the water cycle.

Objective 1:

Describe the relationship between heat energy, evaporation and condensation of water on Earth.

a. Identify the relative amount and kind of water found in various locations on Earth (e.g., oceans have most of the water, glaciers and snowfields contain most fresh water).
b. Identify the sun as the source of energy that evaporates water from the surface of Earth.
c. Compare the processes of evaporation and condensation of water.
d. Investigate and record temperature data to show the effects of heat energy on changing the states of water.

Science language:

vapor
precipitation,
evaporation
clouds
dew
condensation
temperature
water cycle

Objective 2:

Describe the water cycle.

e. Locate examples of evaporation and condensation in the water cycle (e.g., water evaporates when heated and clouds or dew forms when vapor is cooled).
f. Describe the processes of evaporation, condensation, and precipitation as they relate to the water cycle.
g. Identify locations that hold water as it passes through the water cycle (e.g., oceans, atmosphere, fresh surface water, snow, ice, and ground water).
h. Construct a model or diagram to show how water continuously moves through the water cycle over time.
i. Describe how the water cycle relates to the water supply in your community.

Science Benchmark

Weather describes conditions in the atmosphere at a certain place and time. Water, energy from the sun, and wind create a cycle of changing weather. The sun's energy warms the oceans and lands at Earth's surface, creating changes in the atmosphere that cause the weather. The temperature and movement of air can be observed and measured to determine the effect on cloud formation and precipitation. Recording weather observations provides data that can be used to predict future weather conditions and establish patterns over time. Weather affects many aspects of people's lives.

Standard II:

Students will understand that the elements of weather can be observed, measured, and recorded to make predictions and determine simple weather patterns.

Objective 1:

Observe, measure, and record the basic elements of weather.

a. Identify basic cloud types (i.e., cumulus, cirrus, stratus clouds).

b. Observe, measure, and record data on the basic elements of weather over a period of time (i.e., precipitation, air temperature, wind speed and direction, and air pressure).

c. Investigate evidence that air is a substance (e.g., takes up space, moves as wind, temperature can be measured).

d. Compare the components of severe weather phenomena to normal weather conditions (e.g., thunderstorm with lightning and high winds compared to rainstorm with rain showers and breezes).

Objective 2:

Interpret recorded weather data for simple patterns.

a. Observe and record effects of air temperature on precipitation (e.g., below freezing results in snow, above freezing results in rain).

b. Graph recorded data to show daily and seasonal patterns in weather.

c. Infer relationships between wind and weather change (e.g., windy days often precede changes in the weather; south winds in Utah often precede a cold front coming from the north).

Objective 3:

Evaluate weather predictions based upon observational data.

a. Identify and use the tools of a meteorologist (e.g., measure rainfall using rain gauge, measure air pressure using barometer, measure temperature using a thermometer).

b. Describe how weather and forecasts affect people's lives.

c. Predict weather and justify prediction with observable evidence.

d. Evaluate the accuracy of student and professional weather forecasts.

e. Relate weather forecast accuracy to evidence or tools used to make the forecast (e.g., feels like rain vs. barometer is dropping).

Science language:

atmosphere
meteorologist
freezing
cumulus
stratus
cirrus
air pressure
thermometer
air temperature
wind speed
forecast
severe
phenomena
precipitation
seasonal
accuracy
barometer
rain gauge
components

Ideas for connections to earth science

1. A number of demos to teach concepts about weather, the atomosphere, and oceans can be found in chapters 5-7 of *Earth Science for Every Kid*.
2. Many resources for teaching kids about water can be found at: http://ga.water.usgs.gov/edu/index.html
3. See also: http://www.kathimitchell.com/water.htm
4. See also: http://www.proteacher.com/110056.shtml
5. See also: http://www.kidzone.ws/water/
6. Many resources for teaching kids about weather can be found at: http://www.earthsky.com/browse/index.php?c=Weather+%26+Climate
7. See also: http://faldo.atmos.uiuc.edu/w_unit/weather.html

More resources at:
http://www.teach-nology.com/teachers/lesson_plans/science/earth_sciences/

Section 5—Fourth Grade

Science Benchmark

Earth materials include rocks, soils, water, and gases. Rock is composed of minerals. Earth materials change over time from one form to another. These changes require energy. Erosion is the movement of materials and weathering is the breakage of bedrock and larger rocks into smaller rocks and soil materials. Soil is continually being formed from weathered rock and plant remains. Soil contains many living organisms. Plants generally get water and minerals from soil.

Standard III:

Students will understand the basic properties of rocks, the processes involved in the formation of soils, and the needs of plants provided by soil.

Objective 1:

Identify basic properties of minerals and rocks.

a. Describe the differences between minerals and rocks.

b. Observe rocks using a magnifying glass and draw shapes and colors of the minerals.

c. Sort rocks by appearance according to the three basic types: sedimentary, igneous and metamorphic (e.g., sedimentary–rounded-appearing mineral and rock particles that are cemented together, often in layers; igneous–with or without observable crystals that are not in layers or with or without air holes or glasslike; metamorphic –crystals/minerals, often in layers).

d. Classify common rocks found in Utah as sedimentary (i.e., sandstone, conglomerate, shale), igneous (i.e., basalt, granite, obsidian, pumice) and metamorphic (i.e., marble, gneiss, schist).

Objective 2:

Explain how the processes of weathering and erosion change and move materials that become soil.

a. Identify the processes of physical weathering that break down rocks at Earth's surface (i.e., water movement, freezing, plant growth, wind).

b. Distinguish between weathering (i.e., wearing down and breaking of rock surfaces) and erosion (i.e., the movement of materials).

c. Model erosion of Earth materials and collection of these materials as part of the process that leads to soil (e.g., water moving sand in a playground area and depositing this sand in another area).

d. Investigate layers of soil in the local area and predict the sources of the sand and rocks in the soil.

Objective 3:

Observe the basic components of soil and relate the components to plant growth.

a. Observe and list the components of soil (i.e., minerals, rocks, air, water, living and dead organisms) and distinguish between the living, nonliving, and once living components of soil.

Science language:

mineral
weathering
erosion
sedimentary
igneous
metamorphic
topsoil
subsoil
bedrock
organism
freeze
thaw
profile
nonliving
structural support
nutrients

b. Diagram or model a soil profile showing topsoil, subsoil, and bedrock, and how the layers differ in composition.
c. Relate the components of soils to the growth of plants in soil (e.g., mineral nutrients, water).
d. Explain how plants may help control the erosion of soil.
e. Research and investigate ways to provide mineral nutrients for plants to grow without soil (e.g., grow plants in wet towels, grow plants in wet gravel, grow plants in water).

Standard IV:

Students will understand how fossils are formed, where they may be found in Utah, and how they can be used to make inferences.

Objective 1:
Describe Utah fossils and explain how they were formed.

a. Identify features of fossils that can be used to compare them to living organisms that are familiar (e.g., shape, size and structure of skeleton, patterns of leaves).
b. Describe three ways fossils are formed in sedimentary rock (i.e., preserved organisms, mineral replacement of organisms, impressions or tracks).
c. Research locations where fossils are found in Utah and construct a simple fossil map.

Objective 2:
Explain how fossils can be used to make inferences about past life, climate, geology, and environments.

a. Explain why fossils are usually found in sedimentary rock.
b. Based on the fossils found in various locations, infer how Utah environments have changed over time (e.g., trilobite fossils indicate that Millard County was once covered by a large shallow ocean; dinosaur fossils and coal indicate that Emery and Uintah County were once tropical and swampy).
c. Research information on two scientific explanations for the extinction of dinosaurs and other prehistoric organisms.
d. Formulate questions that can be answered using information gathered on the extinction of dinosaurs.

Science language:

infer
environments
climate
dinosaur
preserved
extinct
extinction
impression
fossil
prehistoric
mineral
organism
replacement
trilobite
sedimentary
tropical

Ideas for connections to earth science:

1. Ch. 2 of *Earth Science for Every Kid* has several activities to teach about rocks and minerals.
2. More activities can be found at the Women in Mining web site: http://www.womeninmining.org/Activity.htm
3. Links for teacher resources about rocks, minerals, and fossils can be found at: http://k6educators.about.com/cs/scienceearth1/

More resources at:
http://www.teach-nology.com/teachers/lesson_plans/science/earth_sciences/

Section 6—Fifth Grade

Standard I:

Students will understand that chemical and physical changes occur in matter.

Objective 1:

Describe that matter is neither created nor destroyed even though it may undergo change.

a. Compare the total weight of an object to the weight of its individual parts after being disassembled.
b. Compare the weight of a specified quantity of matter before and after it undergoes melting or freezing.
c. Investigate the results of the combined weights of a liquid and a solid after the solid has been dissolved and then recovered from the liquid (e.g., salt dissolved in water then water evaporated).
d. Investigate chemical reactions in which the total weight of the materials before and after reaction is the same (e.g., cream and vinegar before and after mixing, borax and glue mixed to make a new substance).

Science language:

heat
substance
chemical change
dissolve
physical change
matter
product
reactants
solid,
liquid
weight

Objective 2:

Evaluate evidence that indicates a physical change has occurred.

a. Identify the physical properties of matter (e.g., hard, soft, solid, liquid, gas).
b. Compare changes in substances that indicate a physical change has occurred.
c. Describe the appearance of a substance before and after a physical change.

Objective 3:

Investigate evidence for changes in matter that occur during a chemical reaction.

a. Identify observable evidence of a chemical reaction (e.g., color change, heat or light given off, heat absorbed, gas given off).
b. Explain why the measured weight of a remaining product is less than its reactants when a gas is produced.
c. Cite examples of chemical reactions in daily life.
d. Compare a physical change to a chemical change.
e. Hypothesize how changing one of the materials in a chemical reaction will change the results.

Science Benchmark

Earth and some earth materials have magnetic properties. Without touching them, a magnet attracts things made of iron and either pushes or pulls on other magnets. Electricity is a form of energy. Current electricity can be generated and transmitted through pathways. Some materials are capable of carrying electricity more effectively than other materials. Static electricity is a result of objects being electrically charged. Without touching them, materials that are electrically charged may either push or pull other charged materials.

Standard III:

Students will understand that magnetism can be observed when there is an interaction between the magnetic fields of magnets or between a magnet and materials made of iron.

Objective 1:

Investigate and compare the behavior of magnetism using magnets.

a. Compare various types of magnets (e.g., permanent, temporary, and natural magnets) and their abilities to push or pull iron objects they are not touching.
b. Investigate how magnets will both attract and repel other magnets.
c. Compare permanent magnets and electromagnets.
d. Research and report the use of magnets that is supported by sound scientific principles.

Objective 2:

Describe how the magnetic field of Earth and a magnet are similar.

a. Compare the magnetic fields of various types of magnets (e.g., bar magnet, disk magnet, horseshoe magnet).
b. Compare Earth's magnetic field to the magnetic field of a magnet.
c. Construct a compass and explain how it works.
d. Investigate the effects of magnets on the needle of a compass and compare this to the effects of Earth's magnetic field on the needle of a compass (e.g., magnets effect the needle only at close distances, Earth's magnetic field affects the needle at great distances, magnets close to a compass overrides the Earth's effect on the needle).

Ideas for connections to earth science:

1. metamorphism
2. chemical vs. physical weathering
3. dissolution and precipitation—use halite (table salt)
4. gas can be dissolved in a liquid (gas in magma, carbon dioxide in water)
5. identify minerals by their properties
6. why do minerals have different properties?
7. model magma and rock with ice and water

A number of earth science lesson plans, including some for teaching about the magnetic field of the earth, can be found at:
http://www.teach-nology.com/teachers/lesson_plans/science/earth_sciences/

Section 7—Fifth Grade

Science Benchmark

The Earth's surface is constantly changing. Some changes happen very slowly over long periods of time, such as weathering, erosion, and uplift. Other changes happen abruptly, such as landslides, volcanic eruptions, and earthquakes. All around us, we see the visible effects of the building up and breaking down of the Earth's surface.

Standard II:

Students will understand that volcanoes, earthquakes, uplift, weathering, and erosion reshape Earth's surface.

Objective 1:
Describe how weathering and erosion change Earth's surface.

a. Identify the objects, processes, or forces that weather and erode Earth's surface (e.g., ice, plants, animals, abrasion, gravity, water, wind).
b. Describe how geological features (e.g., valleys, canyons, buttes, arches) are changed through erosion (e.g., waves, wind, glaciers, gravity, running water).
c. Explain the relationship between time and specific geological changes.

Objective 2:
Explain how volcanoes, earthquakes, and uplift affect Earth's surface.

a. Identify specific geological features created by volcanoes, earthquakes, and uplift.
b. Give examples of different landforms that are formed by volcanoes, earthquakes, and uplift (e.g., mountains, valleys, new lakes, canyons).
c. Describe how volcanoes, earthquakes, and uplift change landforms.
d. Cite examples of how technology is used to predict volcanoes and earthquakes.

Objective 3:
Relate the building up and breaking down of Earth's surface over time to the various physical land features.

a. Explain how layers of exposed rock, such as those observed in the Grand Canyon, are the result of natural processes acting over long periods of time.
b. Describe the role of deposition in the processes that change Earth's surface.
c. Use a time line to identify the sequence and time required for building and breaking down of geologic features on Earth.
d. Describe and justify how the surface of Earth would appear if there were no mountain uplift, weathering, or erosion.

Science language:

earthquakes
erode
erosion
faults
uplift
volcanoes
weathering
buttes
arches
glaciers
geological
deposition

Ideas for connections to earth science:

1. Find many lesson plans at: http://www.teach-nology.com/teachers/lesson_plans/science/earth_sciences/
2. Check out Volcano World for ideas! http://volcano.und.nodak.edu/vw.html
3. Or check out the OTHER Volcano World! http://www.volcanoworld.org/

Many demos on these topics can be found in Chapters 2-4 of *Earth Science for Every Kid.*

Section 8—Sixth Grade

Standard I:
Students will understand that the appearance of the moon changes in a predictable cycle as it orbits Earth and as Earth rotates on its axis.

Objective 2:
Demonstrate how the relative positions of Earth, the moon, and the sun create the appearance of the moon's phases.

a. Identify the difference between the motion of an object rotating on its axis and an object revolving in orbit.
b. Compare how objects in the sky (the moon, planets, stars) change in relative position over the course of the day or night.
c. Model the movement and relative positions of Earth, the moon, and the sun.

Standard II:
Students will understand how Earth's tilt on its axis changes the length of daylight and creates the seasons.

Objective 1:
Describe the relationship between the tilt of Earth's axis and its yearly orbit around the sun.

a. Describe the yearly revolution (orbit) of Earth around the sun.
b. Explain that Earth's axis is tilted relative to its yearly orbit around the sun.
c. Investigate the relationship between the amount of heat absorbed and the angle to the light source.

Objective 2:
Explain how the relationship between the tilt of Earth's axis and its yearly orbit around the sun produces the seasons.

a. Compare Earth's position in relationship to the sun during each season.
b. Compare the hours of daylight and illustrate the angle that the sun's rays strikes the surface of Earth during summer, fall, winter, and spring in the Northern Hemisphere.
c. Use collected data to compare patterns relating to seasonal daylight changes.
d. Use a drawing and/or model to explain that changes in the angle at which light from the sun strikes Earth, and the length of daylight, determine seasonal differences in the amount of energy received.
e. Use a model to explain why the seasons are reversed in the Northern and Southern Hemispheres.

Science language:

Earth's tilt
seasons
axis of rotation
orbits
phases of the moon
revolution
reflection

Science Benchmark
The solar system consists of planets, moons, and other smaller objects including asteroids and comets that orbit the sun. Planets in the solar system differ in terms of their distance from the sun, number of moons, size, composition, and ability to sustain life. Every object exerts gravitational force on every other object depending on the mass of the objects and the distance between them. The sun's gravitational pull holds Earth and other planets in orbit. Earth's gravitational force holds the moon in orbit. The sun is one of billions of stars in the Milky Way galaxy, that is one of billions of galaxies in the universe. Scientists use a variety of tools to investigate the nature of stars, galaxies, and the universe. Historically, cultures have observed objects in the sky and understood and used them in

various ways.

Standard III:

Students will understand the relationship and attributes of objects in the solar system.

Objective 1:

Describe and compare the components of the solar system.

a. Identify the planets in the solar system by name and relative location from the sun.
b. Using references, compare the physical properties of the planets (e.g., size, solid or gaseous).
c. Use models and graphs that accurately depict scale to compare the size and distance between objects in the solar system.
d. Describe the characteristics of comets, asteroids, and meteors.
e. Research and report on the use of manmade satellites orbiting Earth and various planets.

Objective 2:

Describe the use of technology to observe objects in the solar system and relate this to science's understanding of the solar system.

a. Describe the use of instruments to observe and explore the moon and planets.
b. Describe the role of computers in understanding the solar system (e.g., collecting and interpreting data from observations, predicting motion of objects, operating space probes).
c. Relate science's understanding of the solar system to the technology used to investigate it.
d. Find and report on ways technology has been and is being used to investigate the solar system.

Objective 3:

Describe the forces that keep objects in orbit in the solar system.

a. Describe the forces holding Earth in orbit around the sun, and the moon in orbit around Earth.
b. Relate a celestial object's mass to its gravitational force on other objects.
c. Identify the role gravity plays in the structure of the solar system.

Ideas for connections to earth science:

1. See Ch. 1 of *Earth Science for Every Kid*.
2. For lesson plans about space, see: http://www.proteacher.com/110020.shtml
3. For lessons about the solar system, see: http://www.proteacher.com/110066.shtml
4. Teach about the volcanoes on Mars and other planets/moons in the solar system.
5. Teach about how the earth is thought to have been formed.

Section 9—Sixth Grade

Standard IV:

Students will understand the scale of size, distance between objects, movement, and apparent motion (due to Earth's rotation) of objects in the universe and how cultures have understood, related to and used these objects in the night sky.

Objective 1:

Compare the size and distance of objects within systems in the universe.

a. Use the speed of light as a measuring standard to describe the relative distances to objects in the universe (e.g., 4.4 light years to star Alpha Centauri; 0.00002 light years to the sun).

b. Compare distances between objects in the solar system.

c. Compare the size of the Solar System to the size of the Milky Way galaxy.

d. Compare the size of the Milky Way galaxy to the size of the known universe.

Objective 2:

Describe the appearance and apparent motion of groups of stars in the night sky relative to Earth and how various cultures have understood and used them.

a. Locate and identify stars that are grouped in patterns in the night sky.

b. Identify ways people have historically grouped stars in the night sky.

c. Recognize that stars in a constellation are not all the same distance from Earth.

d. Relate the seasonal change in the appearance of the night sky to Earth's position.

e. Describe ways that familiar groups of stars may be used for navigation and calendars.

Science language:

asteroids
celestial object
comets
galaxy
planets
satellites
star
distance
force
gravity
gravitational force
mass
scale
solar system
constellation
Milky Way galaxy
speed of light
telescope
universe
sun
light years

Science Benchmark

Heat, light, and sound are all forms of energy. Heat can be transferred by radiation, conduction and convection. Visible light can be produced, reflected, refracted, and separated into light of various colors. Sound is created by vibration and cannot travel through a vacuum. Pitch is determined by the vibration rate of the sound source.

Standard VI:

Students will understand properties and behavior of heat, light, and sound.

Objective 1:

Investigate the movement of heat between objects by conduction, convection, and radiation.

a. Compare materials that conduct heat to materials that insulate the transfer of heat energy.

b. Describe the movement of heat from warmer objects to cooler objects by conduction and convection.

c. Describe the movement of heat across space from the sun to Earth by radiation.

d. Observe and describe, with the use of models, heat energy being transferred through a fluid medium (liquid and/or gas) by convection currents.

e. Design and conduct an investigation on the movement of heat energy.

Objective 2:
Describe how light can be produced, reflected, refracted, and separated into visible light of various colors.

a. Compare light from various sources (e.g., intensity, direction, color).
b. Compare the reflection of light from various surfaces (e.g., loss of light, angle of reflection, reflected color).
c. Investigate and describe the refraction of light passing through various materials (e.g., prisms, water).
d. Predict and test the behavior of light interacting with various fluids (e.g., light transmission through fluids, refraction of light).
e. Predict and test the appearance of various materials when light of different colors is shone on the material.

Objective 3:
Describe the production of sound in terms of vibration of objects that create vibrations in other materials.

a. Describe how sound is made from vibration and moves in all directions from the source in waves.
b. Explain the relationship of the size and shape of a vibrating object to the pitch of the sound produced.
a. Relate the volume of a sound to the amount of energy used to create the vibration of the object producing the sound.
a. Make a musical instrument and report on how it produces sound.

Ideas for connections to earth science:

1. See Chapters 1 and 3 of *Earth Science for Every Kid*.
2. For lesson plans about space, see: http://www.proteacher.com/110020.shtml
3. For lessons about the solar system, see: http://www.proteacher.com/110066.shtml
4. Teach about convection through plate tectonics!
5. See also http://www.geology.com/

Lab 1
The Nature of Science

Learning Objectives

1. Be able to explain the nature of science.

Educational Standards

From *National Science Education Standards* (National Research Council, 1996)

TABLE 6.1. SCIENCE AS INQUIRY STANDARDS

LEVELS K-4	LEVELS 5-8	LEVELS 9-12
Abilities necessary to do scientific inquiry	Abilities necessary to do scientific inquiry	Abilities necessary to do scientific inquiry
Understanding about scientific inquiry	Understanding about scientific inquiry	Understanding about scientific inquiry

Instructions

1. The class will be divided into 5 groups, each assigned a question on the nature of science survey (see next page.)
2. Discuss within your group to see if you can reach a consensus.
3. Each group will report their answer(s) and reasons for those answers.
4. The TA will write on the board 5 basic tenets of the nature of science.
5. You are going to be placed in groups at random. You are to negotiate your storyline with the other group members. Designate one member as the facilitator, one member as the recorder, and one member as the presenter.
6. In your group, take out three of the nine checks from the envelope. Do not look at the other checks.
7. Examine the checks (evidence) and write a short story of what happened. To help in this task, you may want to (a) organize your checks in some specific way, for example, by date or name of the check writer; and/or (b) pay attention to the dates, the people writing the checks, and the addresses on the checks. Draw a line under your story when finished.
8. Take out three more checks from the envelope. Use the additional information to continue/modify/rewrite your story. Again, draw a line under your story when finished.
9. Repeat with the remaining three checks.
10. Prepare to present your final story to the rest of the class. Support your story with evidence (the checks).
11. Discuss as a class how this activity illustrates your 5 tenets.

Nature of Science Survey

Created by Mike G. Rivas

For the following statements, think briefly about the comment and decide whether you agree or disagree. State the rationale for or defend your answer.

1. There is a single scientific method agreed upon and used by those involved in science.

2. Because science is based on evidence, it can be used to answer any question.

3. Imagination and creativity play a significant role in the work of a scientist.

4. Scientific laws and theories are open to debate and can be changed.

5. Because science is based on fact, bias does not play a significant role in scientific activities.

Special Assignment for PS 111B Students

(Don't worry—the PS 110B students have to do this in conjunction with the lectures.)

1. Read the essay "Science As Storytelling" and answer the "questions for thought."
2. Take the online quiz on Blackboard. It will be due before the next class period.
3. Turn in your written answers to your TA for a grade. Each question will be graded as follows. 10 points the clarity of the answers. (Your TA should be able to tell what your opinion is.) 10 points for the validity of the reasoning. (You should provide clear reasoning for taking your positions. "Just because" answers will get no points in this category.)

Lab 2
Properties of Minerals

Instructional Objectives

1. Define "mineral."
2. List common properties of minerals that can be used for mineral identification.
3. Demonstrate techniques to identify unknown mineral samples using diagnostic properties.

Sample K-5 Science Standards Assessed

National, K-4: Scientists use different kinds of investigations depending on the questions they are trying to answer. Types of investigations include describing objects, events, and organisms; classifying them; and doing a fair test (experimenting).

National, K-4: Simple instruments, such as magnifiers, thermometers, and rulers, provide more information than scientists obtain using only their senses.

California, Grade 4: Students know how to identify common rock-forming minerals (including quartz, calcite, feldspar, mica, and hornblende) and ore minerals by using a table of diagnostic properties.

Georgia, Grade 3: Students identify and describe the general characteristics of minerals.

New York, Grades 5-8: Students will use identification tests and a flow chart to identify mineral samples.

Utah, Grade 4: Students will distinguish between crystalline and non-crystalline substances.

Discussion

A **mineral** is a naturally occurring inorganic, element or compound with a specific atomic structure and a characteristic chemical composition. Every mineral can be identified by a unique set of chemical and physical properties.

Why do state curriculum standards ALWAYS require that students learn basic mineral identification? We believe one reason is that if you know the identity of a mineral you find, you can identify it as a possible resource to be used, and understand what must be done to extract those resources (i.e., mining). It's bad for kids to grow up consuming resources without understanding what must be sacrificed to make that possible. Another reason is that if you know the identity of a mineral, you can say something about the geologic history of the area where it was found. A given mineral will only occur under certain conditions (i.e., its constituent elements must be present in sufficient amounts, particular temperature and pressure ranges must prevail, and water may need to be present.) If you find a mineral, then you know that the conditions needed to form it must once have prevailed in that area. Perhaps what is now the surface was once deep underground, or covered by an ocean.

A. Physical Properties of Minerals

1. **Color**. The color of a mineral is caused by the interaction of light with the chemical constituents and crystal structure of the mineral. However, most minerals contain some impurities that can strongly influence the color of individual mineral samples. Therefore, color is not usually a reliable characteristic for identifying minerals. For example, quartz may be white or colorless when it is pure, but trace amounts of iron in the mineral can cause it to appear purple.

2. **Luster**. Luster is the appearance of the mineral surface in reflected light. Minerals with *metallic* luster either look shiny like polished metal or dull like rust. Minerals with *nonmetallic* luster may be described as glassy, pearly, resinous, silky, earthy, or greasy.

3. **Streak**. Streak is the color of the powder of a mineral. It is obtained by rubbing a sample across unglazed porcelain. The streak color commonly differs from the mineral color.

4. **Crystal form**. Crystal form is a characteristic feature of minerals that have grown without physical interference. The geometric form or shape of the crystal is an expression of the mineral's internal atomic structure.

5. **Cleavage**. The cleavage of a mineral is its tendency to break along certain planes. The planes of cleavage are parallel to the weakest planes in the mineral's atomic structure. A good example of cleavage is shown by the mica minerals (muscovite and biotite), which break along thin basal sheets. Do not confuse cleavage with crystal form. When trying to identify unknown minerals, remember that crystal form represents the shape that the mineral developed as it grew. Cleavage has to do with how the mineral will break if exposed to stress after its formation.

6. **Fracture**. Some minerals do not exhibit cleavage, but instead show fracture. Fracture is any break that is not along cleavage planes. Quartz is an example of a mineral that displays fracture instead of cleavage.

7. **Hardness**. A mineral's hardness is its relative ability to resist abrasion. Hardness is measured by comparing a mineral sample to a set of standard minerals of known hardness. The scale of standard mineral hardness is called the Moh's Scale (Table 3.1). Minerals with low hardness values are soft and can be scratched by materials with higher hardness values.

8. **Specific gravity**. Specific gravity is determined by comparing the weight of a mineral to the weight of an equal volume of water. For instance, a mineral that weighs twice as much as an equal volume of water would have a specific gravity of 2.0. While specific gravity is usually determined in the lab, it can also be useful in the field when you want to make comparisons between two mineral samples. Often, specific gravity can be a determining factor between minerals that otherwise look much alike. True gold, for example, has a specific gravity of 19.3; fool's gold, however, has a specific gravity only 5.0. The true gold will feel much heavier than the fool's gold.

B. Chemical Properties of Minerals

1. **Effervescence**. Effervescence is the most important chemical property used in the identification of common minerals. Effervescence is the "fizzing" that occurs when a mineral containing calcium carbonate reacts with a 10% hydrochloric acid solution. Calcite and dolomite are two minerals that show effervescence.

Lab Activities

A. How do We Study the Diagnostic Properties of Minerals? (Suggested class time: 30 minutes.)

Many of the diagnostic properties of minerals can be determined by simply looking at the mineral sample and making an observation. Color, luster, crystal form, cleavage, and fracture, for example, can usually be determined by simply looking at a sample. Other mineral properties, such as hardness, specific gravity, and effervescence require a little more work.

In this portion of the lab, you will observe color and luster and learn ways to identify hardness and effervescence. During the next lab period, you will apply all of the diagnostic properties to identifying some unknown mineral samples.

You will work in 3 groups for the following lab activities. At the end of the activity, one group will report their findings on color and luster; one group on hardness; and one group on effervescence.

> **Focus on the Nature of Science:**
> **Science Demands Evidence**
>
> "Science demands evidence. . . Because of this reliance on evidence, great value is placed on the development of better instruments and techniques of observation, and the findings of any one investigator or group are usually checked by others."
> ---taken from www.project2061.org
>
> Observing the properties of minerals is part of meeting science's demand for evidence.

Color and Luster

Materials needed: Several unknown mineral samples

Activity:

1. Observe and record the color of each mineral sample.
2. Observe and record the luster of each mineral sample.

Hardness

Materials needed:
Several unknown mineral samples of varying hardness
A copper penny
An iron nail
A glass plate
Moh's Hardness Scale

Activity:

1. Use your fingernail to try to scratch each mineral sample. If you can scratch the sample, its hardness is less than 2. If you cannot scratch the sample, its hardness is greater than 2. Record your findings in Table 3.2.
2. Use the copper penny to try to scratch each mineral sample. If you can scratch the sample, its hardness is less than 3. If you cannot scratch the sample, its hardness is greater than 3. Record your findings in Table 3.2.

3. Use the iron nail to try to scratch each mineral sample. If you can scratch the sample, its hardness is less than 5. If you cannot scratch the sample, its hardness is greater than 5. Record your findings in Table 3.2.

4. Try to scratch the glass plate with each mineral. If you can scratch the glass, the sample's hardness value is greater than 6. If you cannot scratch the glass, the sample's hardness value is less than 6. Record your findings in Table 3.2.

5. Estimate the hardness value of each mineral sample.

Effervescence

Materials needed: Several unknown mineral samples
Dropper bottle containing 10% hydrochloric acid solution

Activity:

1. Place 2 to 3 drops of acid solution on the surface of each mineral sample.

2. Observe whether of not fizzing occurs. Record your findings.

SCIENCE AS INQUIRY:

Focus on the National Science Education Standards

According to the *National Science Education Standards*, one of the five essential skills for doing scientific inquiry is the ability to

EMPLOY SIMPLE EQUIPMENT AND TOOLS TO GATHER DATA AND EXTEND THE SENSES.

In this lab, you use tools and make observations about the properties of

Table 3.1. The Moh's Hardness Scale for Minerals

Hardness	Mineral	Comments
10	Diamond	Hardest mineral known
9	Corundum (Sapphire/Ruby)	Harder than Topaz
8	Topaz	Harder than Quartz
7	Quartz	Scratches Glass
6	Microcline	Suitable for gems
5	Apatite	About the hardness of teeth
4	Fluorite	Cannot be scratched with a nail
3	Calcite	Difficult to scratch with a nail
2	Gypsum	Easily scratched with nail
1	Talc	Very soft, chalk-like

Table 3.2 Data Table for In-Class Lab Activities

Sample Number	Color	Luster	Estimated Hardness	Effervescence (Yes or No)
1				
2				
3				
4				
5				

Questions for Thought

Using the definition of cleavage given in the Discussion, propose a reason why quartz does NOT display cleavage. What does the absence of cleavage in the mineral quartz suggest about its atomic structure?

Suppose you have 2 unknown minerals. You do a hardness test as outlined in this lab and both are harder than glass. How could you then determine which of the 2 minerals is harder than the other? Can you think of a way to estimate their hardness values?

Using the definition of specific gravity given in the Discussion, propose an experiment that would estimate the specific gravity of a mineral sample. (HINT: How could water be used to estimate a mineral sample's specific gravity?)

Lab 3
Identifying Unknown Mineral Samples

Instructional Objectives

1. Use the diagnostic properties of minerals to determine the identity of unknown mineral samples.

2. Use flow charts and tables to assist in the identification of unknown mineral samples.

Sample K-5 Science Standards Assessed

National, Grades K-4: Students should develop an understanding of the properties of earth materials.

California, Grade 4: Students know how to identify common rock-forming minerals (including quartz, calcite, feldspar, mica, and hornblende) and ore minerals by using a table of diagnostic properties.

Georgia, Grade 3: Students identify and describe the general characteristics of minerals.

New York, Grades 5-8: Students will use identification tests and a flow chart to identify mineral samples.

Utah, Grade 4: Students will distinguish between crystalline and non-crystalline substances.

Discussion

In the previous lab, we learned about some of the properties of minerals that can be used to identify them. These included color, luster, cleavage, fracture, hardness, streak, specific gravity, and effervescence. In this lab, we will use these diagnostic properties of minerals to identify some unknown samples.

One common way of applying the diagnostic properties to mineral identification is to use a flow chart or table that describes the properties of many known minerals. Such charts can be found in many geology textbooks. A chart of common mineral diagnostic properties is shown in Figure 4.1.

FOCUS ON THE NATURE OF SCIENCE:

Scientific Knowledge is Durable

While scientific ideas are subject to change as new observations challenge prevailing theories, most scientific *knowledge* is durable.

The minerals that are presented in your flow chart have been studied extensively by geologists, and their properties and names are considered scientific knowledge. For example, the hardness of quartz or the specific gravity of

Note that while there are thousands of known minerals on the earth, most identification charts only list a few of the most common minerals. These most common minerals are also the ones most commonly found in rocks. Or they are minerals such as gold or lead that have important economic value. Other, less common minerals are often identified when necessary by laboratory procedures.

Figure 3.1. Diagnostic Properties of Some Common Rock-forming Minerals

Metallic Minerals

Mineral	Cleavage	Color	Luster	Density	Hardness	Chemical Formula	Crystal Form	Streak	Notes
Hematite	None	"rusty" or silver	Earthy or metallic	5.3	6.5	Fe_2O_3		Red-brown	
Pyrite	Poor	Pale brass yellow	Metallic	5	6.5	$Fe^{2+}S_2$	Cubic	Black to gray	Known as fool's gold
Galena	Cubic	light lead gray or dark lead gray	Metallic	7.2 – 7.6	2.5	PbS	Cubic	Black to gray	Very heavy because of the lead content
Graphite		Steel gray to iron black	Dull metallic	2	1	C		Black-gray	Marks paper, feels greasy
Magnetite		Black to dark gray	metallic	5.2	6	Fe_3O_4	Octo-hedral	black	Magnetic!

Non-Metallic Minerals

Mineral	Cleavage	Color	Luster	Density	Hardness	Chemical Formula	Crystal Form	Streak	Notes
Talc	Perfect in one direction	pale green, white, gray white, yellowish white, brownish white	Pearly or greasy	2.7 to 2.8	1	Mg3Si4O10-(OH)2	Usually clay masses	Colorless	Soapy feel
Kaolinite	None Visible	White to red	earthy	2	1.2	$Al_4Si_4O_{10}(OH)_8$	Clay masses	Colorless	Sticks to tongue, plastic when wet
Halite	Cubic	White, clear	glassy	2.2	2.5	NaCl	Cubic	Colorless	Glassy luster
Calcite	Rhombohedral	Colorless, white, pink, yellow, brown	vitreous	2.7	3	$Ca(CO_3)$		Colorless	Effervesces
Gypsum	Good in one direction	white, colorless, yellowish white, greenish white, brown	vitreous	2.3	2	$Ca(SO_4)\cdot 2(H_2O)$	Tabular	Colorless	Transparent to translucent
Muscovite	Basal	white, gray, silver white, brownish white, greenish white	vitreous /Pearly	2.8	2-2.5	$KAl_3Si_3O_{10}$-$(OH)_{1.9}F_{0.1}$	Tabular	Colorless	Transparent in sheets, can be cleaved into thin sheets
Biotite	Basal	dark brown, greenish brown, blackish brown, yellow, or white	vitreous	2.8 – 3.4	2.5 – 3	$KMg_{2.5}Fe^{2+}{}_{0.5}AlSi_3O_{10}(OH)_{1.75}F_{0.25}$	Tabular	Colorless	Can be cleaved into thin sheets
Quartz	None	brown, colorless, violet, gray, yellow	vitreous	2.6	7	SiO_2	Pointed prisms with 6 sides	Colorless	Vitreous luster
Fluorite	Perfect in four directions	Green, purple, yellow, pink	vitreous	3	4	CaF_2	Octahedral	Colorless	Transparent to translucent
Apatite	Indistinct	white, yellow, green, red, blue	vitreous	3.2	5	$Ca_5(PO_4)_3(OH,F,Cl)$	Long, hexagonal prisms	Colorless	Vitreous luster

Garnet	None	Red or brown	glassy	3.5-4.5	6.5-7	Fe, Mg, Ca, Al silicates	12-sided	Color-less	Conchoidal fracture
Pyroxene Group	Perf-ect in two direc-tions	black	Vitreous /pearly on cleavage surfaces	3.5	6	$XY(Si, Al)_2O_6$ (where X,Y are metal ions)	Short, prisms	Color-less	Cleavage is often poorly expressed, and cleavage directions are 90° apart
Amphibole Group	Perf-ect in two direc-tions	Black or brown-ish grey	vitreous	3	5.5 - 6	Complex silicate	Short prisms	Color-less	Cleavage directions ~60 or 120° apart
Olivine	None	Olive to gray-green	glassy	3.5-4.5	7-7.5	$(Fe,Mg)_2SiO_4$		Color-less	Often small, glassy grains, conchoidal fracture
Orthoclase	Good in two direc-tions	Off white, orange to brown	Vitreous silky to dull	2.5	6	$KAlSi_3O_8$		White	Vitreous to dull luster, cleavage directions 90° apart
Plagio-clase Feldspars	Good in two direc-tions	Usually white		2.6	6	$NaAlSi_3O_8$		Color-less	Presence of striations

Lab Activities

You will work in groups for this lab activity. Each group will be given the same 15 minerals to identify. After all groups have identified their 15 samples, each group may be called on to describe and name a few of their samples for the rest of the class.

Materials needed:
- Samples of 15 common rock-forming minerals
- Copper penny
- Iron nail
- Glass scratch plates
- Streak plates
- Dropper bottle with 10% hydrochloric acid solution

Activity:

1. Record the color and luster and any obvious signs of cleavage or crystal form for each mineral sample.
2. Do a streak test for each mineral by rubbing the sample against a porcelain streak plate. Record the color of the powder.
3. Do a hardness test for each sample.
4. Do an effervescence test for each sample.
5. Use your mineral identification flow chart to identify each sample.

Table 3.1. Data Table for In-class Lab Activity

Sample #	Color	Luster	Streak	Crystal Form	Cleavage	Hardness	Effervescence (yes or no)
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							

Check it Out!

The Mineralogical Society of America has an awesome website for kids.
The site gives lots of kid-friendly information on minerals
and has a tool that students can use to identify their own mineral samples!
http://www.minsocam.org/MSA/K12/K_12.html

Questions for Thought

Note that some of the minerals come in different colors (quartz, for example). Why do different colors exist for different samples of the same mineral?

What are some effective ways of distinguishing between different minerals that otherwise look a lot alike (quartz vs. calcite, or gypsum vs. talc, for example)?

Explain the importance of performing several property tests to identify the name of a mineral.

Lab 4
Rock Types

Learning Outcomes

1. Be able to examine a rock and tell what category it fits into.
2. When you categorize a rock, be able to tell part of its story.

Sample K-5 Science Standards Assessed

California, Grade 4: Students know how to differentiate between igneous, sedimentary, and metamorphic rocks by referring to their properties and methods of formation (rock cycle).

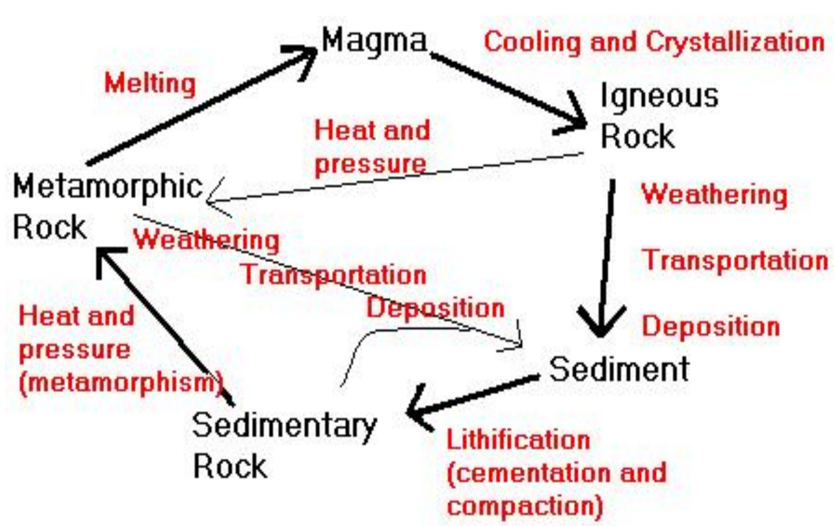
Maine, Grades 5-8: Students classify and identify rocks and minerals based on their physical and chemical properties, the compositions, and the processes which formed them.

Texas, Grade K: Students will describe properties of rocks, soils, and water.

Discussion

We could classify rocks in any number of ways—color, exact mineral content, elements present, etc. But since geologists are really interested in making stories about how the Earth came to be in its present state, we decided to classify rocks first by how we think they formed. Secondarily, we classify them by properties that we think tell us even more specifics about how they formed. In this lab, you will learn the basics of rock classification, so that you can tell stories about how particular rocks came to be.

The Rock Cycle. Stories about how particular rocks came to be will always allude to the **rock cycle**. The rock cycle describes how rocks are "born" and altered through time by various earth processes. This and the next several labs will discuss concepts related to the rock cycle.



Let's begin our examination of the rock cycle with a "visit" to the Hawaiian Islands to the world's most active and best-studied volcano, Kilauea. This famous volcano, like others across the globe, is the birthplace of thousands of tons of rocks. The rocks are "born" as volcanic eruptions eject massive amounts of **magma** onto Earth's surface. Remember that magma is a large body of hot liquid rock and minerals. When the magma is ejected onto the Earth's surface, it is classified as **lava**, which cools into a solid rock around the base of the volcano. Rocks formed from cooled magma or lava are classified as **igneous** rocks.

Moving east to Zion National Park in Utah, we find rocks that were formed under very different circumstances—for example, the well-known Navajo Sandstone Formation. This rock formation was made from ancient sand dunes. The sandstone rocks that make up the Navajo Sandstone Formation began millions of years ago as tiny grains of sand in a prehistoric desert. Over time, winds carried the sand and deposited it into giant sand dunes. Eventually the sand was cemented together as sandstone due to minerals precipitated in the pore spaces from groundwater, and compacted due to overlying layers of sediment and rock. Rocks that form by the aggregation of pieces of pre-existing rock and/or the precipitation of minerals from water are classified as **sedimentary** rocks**.**

Although these sandstone rocks began as a collection of individual grains of sand, the sand grains themselves had to come from somewhere and something else. Where might these sand grains may have originated? The sand grains may have broken off rocks formed by igneous processes. Or they may have broken off older sandstone rocks.

Now let's "visit" east Greenland, where we find a third type of rock. Millions of years ago there, magma deep inside the Earth forced its way into an existing rock and solidified. This created an igneous rock. Then, intense pressure in the Earth caused the rock to up-heave, fold, and crumple, until it recrystallized to became an entirely new rock—a **metamorphic** rock. That new rock now makes up a mountain formation in Greenland

Because the Earth is dynamic, rocks are always changing. Minerals that make up rocks are constantly moved and acted upon by the environment. Environmental agents change one type of rock into an entirely new rock. The web of environmental processes that forms and changes rocks is known as the **rock cycle** (Figure 5.1). The rock cycle is always at work and never ends. Following are the three types of rocks that participate in the rock cycle:

1. **Igneous** rocks are created when molten material such as magma (within the Earth) or lava (on the surface) cools and hardens. The hot material crystallizes into different minerals. The properties and sizes of the various crystals depend on the magma's composition and cooling rate. Igneous rocks that crystallized underground have bigger crystals, and those that crystallized above ground have crystals that are usually too small to see.

2. **Sedimentary** rocks are made up of sediments eroded from igneous, metamorphic, other sedimentary rocks, and even the remains of dead plants and animals. These are called "detrital sedimentary rocks" because they are made from "detritus," which is bits of broken up rock. They can also be precipitated from chemicals dissolved in water at the Earth's surface. These are called "chemical sedimentary rocks." These materials are deposited in layers, or strata, and then may be cemented and compacted into rock. Most fossils are found in sedimentary rocks.

3. **Metamorphic** rocks are produced when sedimentary, igneous, or other metamorphic rocks are recrystallized by heat and/or pressure. The word "metamorphic" comes from the Greek language, and means "to change form."

Telling Them Apart. How can you tell what kind of rock a particular sample is, and specifically how it formed? Sometimes it is hard, but if you know a few basic principles, you will be able to figure it out most of the time. Here they are:

1. As mineral crystals grow, they often fill up the available space and grow together. A rock that has nice, interlocking crystals that have all grown together is usually pretty strongly held together. Therefore, igneous, metamorphic, and chemical sedimentary rocks usually feel pretty solid. On the other hand, detrital sedimentary rocks that form from bits of older, broken up rocks, tend to be held together a little more loosely. If you rub your fingers against them, you can often rub off pieces of sediment.
2. Mineral crystals like to grow big if they can, but they need two things to accomplish it. First, they need time to grow. Second, it helps if the temperature is higher, so that the molecules that make up the minerals can move around faster. Therefore, igneous and metamorphic rocks often (but not always) have nice, big crystals.
3. For both igneous and metamorphic rocks, crystal sizes actually range from microscopic to fairly large. For igneous rocks, the size tells us something about how fast the molten rock cooled. If the cooling was slow, because the magma was deep underground, then the crystals have time to grow fairly large. If the cooling was rapid after the lava was ejected onto the surface of the Earth from a volcano, then most of the crystals will be too small to see.
4. Minerals are crystalline (meaning they have ordered atomic structures,) so they also like to grow with nice crystal forms. But to do this, they need space. Therefore, minerals that grow from chemicals dissolved in water (chemical sedimentary rocks) and volcanic igneous rocks that form from lava that has gas bubbles often have spaces where nicely formed little crystals show up. Also, volcanic rocks often have a few, nicely formed crystals that seem to be “floating” in a mass of material that has crystals too small to see. That’s because those crystals formed when the molten rock was still underground, and they *were* floating in the magma. Then the whole thing was ejected onto the surface and cooled rapidly.
5. Void spaces that look like gas bubbles are a big clue that you are looking at a volcanic igneous rock. When magma is deep underground, there is too much pressure to allow bubbles to form. As it moves up toward the surface, the pressure is released, and gases dissolved in the magma can be released to form bubbles. All these bubbles forming actually drives the magma upward and causes volcanic eruptions. (The same thing happens with soda. When the lid is on, the bottle is pressurized, so the dissolved carbon dioxide stays in the water. But when the pressure is released, lots of bubbles form. If you have shaken the bottle, the bubbles often form even more quickly, causing an “eruption” all over your clothes.)
6. Many (not all) metamorphic rocks have crystals that are all oriented in the same direction. This occurs because, at the time of their formation, they were getting squashed from the sides due to tectonic forces. (Tectonic plates smashing together, etc.)
7. Usually, when minerals precipitate from chemicals dissolved in water, only one mineral forms at a time. Therefore, most chemical sedimentary rocks are only made of one mineral. For example, limestone is made of calcite, dolostone is made of dolomite, rock salt is made of halite, and rock gypsum is made of gypsum. (Sometimes sandstone, a detrital sedimentary rock, is made almost exclusively of quartz because quartz is very resistant to weathering. But if you rub its surface, it feels gritty and you might rub off some sand, so you can tell it is detrital.)
8. When a sedimentary rock that is made of only one mineral undergoes metamorphosis, its minerals usually just grow bigger, and interlock more strongly. For example, marble is made of calcite, and is metamorphosed limestone (or dolostone.) You can tell it apart from limestone because it has large, grainy crystals. Quartzite is made of quartz, and is metamorphosed sandstone.

Lab Activity

The activity is simple. Your TA will split you into about 4-5 groups, and hand out a set of three rocks to each group. Each set will have one igneous, one metamorphic, and one sedimentary rock. Your job will be to do the following:

1. Decide which category the rocks fit into.
2. Explain what clues you were using to decide, in each case.
3. For igneous rocks, tell whether they formed underground or aboveground (volcanic.)
4. For sedimentary rocks, tell whether they formed from bits of other rocks (detrital) or were precipitated from water (chemical.)
5. Tell the story of how each rock formed.

As time permits, the different groups can switch sets of rocks. The TA will circulate through the groups and tell you whether you got the answers right—but only AFTER you have given it a try. ("A try" isn't just guessing at the identification. You have to come up with reasons.)

Rock 1

- **Rock Type:**
- **Reasoning:**

- **Detrital/Chemical or Volcanic/Underground?**

- **The Story:**

Rock 2

- **Rock Type:**
- **Reasoning:**

- **Detrital/Chemical or Volcanic/Underground?**

- **The Story:**

Rock 3

- **Rock Type:**
- **Reasoning:**

- **Detrital/Chemical or Volcanic/Underground?**

- **The Story:**

Rock 4

- **Rock Type:**
- **Reasoning:**

- **Detrital/Chemical or Volcanic/Underground?**

- **The Story:**

Rock 5

- **Rock Type:**
- **Reasoning:**

- **Detrital/Chemical or Volcanic/Underground?**

- **The Story:**

Rock 6

- **Rock Type:**
- **Reasoning:**

- **Detrital/Chemical or Volcanic/Underground?**

- **The Story:**

Rock 7

- **Rock Type:**
- **Reasoning:**

- **Detrital/Chemical or Volcanic/Underground?**

- **The Story:**

Rock 8

- **Rock Type:**
- **Reasoning:**

- **Detrital/Chemical or Volcanic/Underground?**

- **The Story:**

Rock 9

- **Rock Type:**
- **Reasoning:**

- **Detrital/Chemical or Volcanic/Underground?**

- **The Story:**

Use the backs of the pages for more rocks.

Lab 5
Igneous Rocks

Instructional Objectives

3. Understand the effect of cooling rate on the textures and chemical compositions of igneous rocks.
4. Describe the processes by which igneous rocks are formed.
5. Recognize different textures found in igneous rocks.
6. Explain the rock cycle concept.
7. Identify several common igneous rocks.

Sample K-5 Science Standards Assessed

California, Grade 4: Students know how to differentiate between igneous, sedimentary, and metamorphic rocks by referring to their properties and methods of formation (rock cycle).

Maine, Grades 5-8: Students classify and identify rocks and minerals based on their physical and chemical properties, the compositions, and the processes which formed them.

Texas, Grade K: Students will describe properties of rocks, soils, and water.

Discussion

Igneous Rock Classification. Igneous rocks begin as **magma** (liquid rock within the earth) or as **lava** (magma that has reached the earth's surface). They are classified by 1) composition—what minerals they contain, and 2) texture—the size, shape, and arrangement of the crystals. These attributes were chosen because they tell us important things about the story of the rock.

The composition of the rock tells us something about how hot the magma was. Different minerals form or melt at different temperatures, so the minerals in an igneous rock tell us how hot it must have been for all the minerals to have been melted at one time. A general rule is that minerals with more silica (silicon and oxygen) form or melt at lower temperatures, and those with less silica form or melt at higher temperatures.

When we look at the texture of an igneous rock, we are mainly looking at the size of its crystals. This tells us something about where the rock formed. Slow cooling can allow for the development of large, well-formed crystals; whereas rapid cooling results in crystals so small that they cannot usually be seen with the naked eye. Igneous rocks that form inside the earth and have large crystals are called **intrusive** or **plutonic** rocks. Igneous rocks that form at the earth's surface and have small crystals are called **extrusive** or **volcanic** rocks.

<u>Igneous Textures</u>

1. **Phanaritic**. Phanaritic texture develops when the rock solidifies slowly underground and develops large crystals which can be seen easily with the unaided eye.
2. **Aphanitic**. Aphanitic texture develops when the rock solidifies rapidly above ground and develops small crystals which are not visible to the unaided eye.
3. **Porphyritic**. Porphyritic texture develops when slow cooling is followed by more rapid

cooling. The resulting rock contains some large crystals embedded in regions of smaller or even invisible crystals. For example, a rock may be *porphyritic phaneritic*, meaning that some crystals are much larger than the others, but all are visible to the unaided eye. Also, a rock may be *porphyritic aphanitic*, meaning that visible crystals are surrounded by a matrix of smaller ones that are invisible to the unaided eye.

4. **Glassy**. Glassy texture develops when cooling occurs so rapidly that there is no time for the development of crystal grains. This may occur when magma is erupted quickly into the air or into a body of water.

Igneous Compositions

1. **Ultramafic**. Ultramafic igneous rocks are characterized by high amounts of iron and magnesium in their mineral constituents, and a low amount of silica (<45%.) They often contain olivine, which has a green color, and pyroxene. They are also relatively dense because of all the iron and magnesium they contain. Ultramafic rocks are usually formed deep within the earth.
2. **Mafic**. Mafic igneous rocks also contain high amounts of iron- and magnesium-bearing minerals, but less so than the ultramafic rocks. They also contain somewhat more silica (45-55%.) They are dark in color (usually blackish) because of all the iron-bearing minerals, and are the most abundant rock type in the earth's crust. They form at high temperatures.
3. **Intermediate**. Intermediate igneous rocks contain between 55% and 65% silica and fewer iron- and magnesium-bearing minerals than the previous two igneous rock types. Minerals with high silica content often have a lighter color than that of iron- and magnesium-rich minerals. They form at intermediate temperatures.
4. **Felsic**. Felsic igneous rocks contain more silica (>65%) than any other igneous rock type. They solidify at low temperatures and have abundant quartz and feldspar. Felsic rocks are light in color because they contain very little of the darker iron and magnesium minerals. They form at low temperatures (for molten rock.)

Table 5.1 Textures and Compositions of Common Igneous Rocks

Rock Name Phaneritic Texture (Intrusive)	Rock Name Aphanitic Texture (Extrusive)	Composition	Essential Minerals	Accessory Minerals
Granite	*Rhyolite*	Felsic	Quartz, feldspar	Mica, hornblende, pyroxene, apatite
Diorite	*Andesite*	Intermediate	Feldspar, ferro-magnesian minerals	
Gabbro	*Basalt*	Mafic	Feldspar, pyroxene	
Peridotite	*Komatiite*	Ultramafic	Pyroxene, olivine	

Other igneous rocks you will encounter:

1. *Obsidian*—has a glassy texture; although it is usually black, it's mineral composition is actually felsic
2. *Pumice*—has a frothy or bubbly look; is light in weight and color; felsic in mineral composition; will float in water
3. *Tuff*—has a frothy or bubbly look; made of fragments of solidified lava; has intermediate or felsic mineral composition

Lab Activities

You will work in 3 to 4 different groups for this lab. Record your observations in Table 5.2.

A. Observing the Properties of Igneous Rocks
(Suggested Class Time: 15 minutes)

Materials Needed: Igneous Rock Samples 1 through 11

Hand Lens or microscope

Activity:

1. Observe and record the following properties of your igneous rock samples: color, crystal size, and density (heavy or light for its size).

B. Relating Igneous Rock Properties to their Environment of Formation
(Suggested Class Time: 25 minutes)

Materials Needed: Igneous Rock Samples 1 through 11

Activity:

1. Based on your observations in Part A, classify each of your samples as intrusive or extrusive.
2. Based on the color of each sample, determine if the sample was derived from felsic, intermediate, mafic or ultramafic magma.
3. Use Table 5.1 to determine the most likely name of each rock sample.
4. Assume that all of your intrusive samples were formed from the same magma source. Order them in order of progressive crystallization:

Science as Inquiry:
Focus on the National Science Education Standards

Scientists develop explanations using observations (evidence) and what they already know about the world (scientific knowledge). Good explanations are based on evidence from investigations.

In this lab, you make observations (collect evidence) and then use your observations to develop explanations about the environments in which your igneous rock samples were formed.

1. ________________________

2. ______________________

3. ______________________

4. ______________________

Table 5.2. Data Observations for In-Class Activities

Sample #	Observations	Location of Formation	Type of Magma	Name of Rock
1				
2				
3				
4				
5				
6				
7				
8				
9				

10				
11				

Questions for Thought

Fossilized remains are not usually found in igneous rocks. Why?

Pick one of the igneous rock samples from today's lab. Sketch a diagram of the rock cycle and show where the rock you picked would be found on the rock cycle.

Lab 6
Weathering

Instructional Objectives

1. Define "weathering."
2. Identify processes of mechanical and chemical weathering.
3. Understand the role of weathering in the rock cycle.
4. Understand the factors that influence weathering—such as climate, living organisms, and time.

Sample K-5 Science Standards Assessed

Connecticut, Grades K-4: Students explain that soil is made partly from weathered rock; students describe how waves, wind, water, and ice shape and reshape the Earth's surface by eroding rock and soil in some areas and depositing them in others.

Louisiana, Grades K-4: Students observe and describe variations in soil.

North Carolina, Grade 1: Students will determine the properties of soil: composition, texture, capacity to retain water, color, capacity to support life.

West Virginia, Grade 4: Students will compare and explain the relative time differences to erode materials.

Discussion

Weathering is the process by which rocks, minerals, and soils are broken down by the attack of physical and chemical forces at the earth's surface. Weathering is an ongoing geologic process—it is always occurring and occurs everywhere on the earth. Weathering processes are classified as either mechanical or chemical.

Mechanical weathering. Mechanical weathering results in the disintegration of materials. Under mechanical weathering, materials are broken down into smaller and smaller pieces, but they do not change in terms of their chemical composition.

1. **Heat effects**: temperature changes may cause **thermal expansion** and contraction of the material, weakening the material and causing it to break.

2. **Frost wedging**: freezing of pore water (water found in tiny cracks) in rocks may exert pressures that break apart the rock.

3. **Water and wind**: small particles carried by water and wind may abrade materials and facilitate their breaking down to smaller particles.

4. **Plants and animals**: plant roots may grow into rock cracks and wedge apart the rocks. Small and large burrowing animals can churn the soil and rock materials of an area. Or human-activated machines can churn the soil and break rock materials.

Chemical weathering. Chemical weathering results in the decomposition of materials. Materials are broken down and altered by chemical processes. The processes result in weathering products that are more inert, fine-textured, more highly hydrated (contain more water), and softer than the products produced by mechanical weathering alone. Often, mechanical weathering facilitates chemical weathering by making materials smaller and more vulnerable to chemical attack. Mechanical and chemical weathering may—and often do—occur simultaneously. For instance, both the presence of water and elevated temperature promote chemical weathering and certain types of mechanical weathering.

1. **Dissolution**: Water-soluble minerals are dissolved to form aqueous ions (charged chemical species). Dissolution reactions are generally the first stage of chemical weathering. They can accelerate other weathering processes by making rocks more porous. Consider, for example, a rock containing the mineral gypsum ($CaSO_4$). In this case, the solid mineral is dissolved in water and broken down to two distinct chemical species, the calcium ion (Ca^{2+}) and the sulfate ion (SO_4^{2-}):

    i. $CaSO_4 + H_2O = Ca^{2+} + SO_4^{2-}$

2. **Hydrolysis**: reaction of water with ions or elements of minerals. The water molecule splits into H^+ and OH^- ions, which can then displace other ions from a mineral's structure. For example, H^+ can replace K^+ in potassium feldspar ($KAlSi_3O_8$) to produce kaolinite ($Al_2Si_2O_5(OH)_4$). (Water molecules also participate in the reaction.)

3. **Oxidation**. Reaction with oxygen to form oxides and hydroxides. For example, iron in mafic igneous rocks can combine with oxygen to form the iron oxide mineral hematite. Also, iron pipes rust when exposed to air and water, and rust is a type of iron oxide.

Some factors that influence weathering include time, climate, living organisms, and mineral stability. The longer a rock or mineral is exposed to weathering, the more it will decompose. Climate plays an important role in both mechanical and chemical weathering, not only because of temperature and moisture effects, but also because of its influence on vegetation and animal life. The stability of different minerals, when exposed to weathering processes, varies greatly. In general, minerals that formed under conditions that were greatly different than conditions at the surface of the earth are more easily weathered. For example, olivine and pyroxene form at very high temperatures high temperature (crystallized early from a high-temperature magma), and are some of the most easily weathered common minerals. Minerals such as muscovite and quartz, which form at lower temperatures (crystallized later from a low-temperature magma), are much more resistant to weathering.

Weathering is a crucial part of the rock cycle because it breaks down existing materials and creates smaller materials. These smaller materials accumulate as **sediments**, which are later deposited and compacted into new rocks.

FOCUS ON THE NATURE OF SCIENCE:
The World is Understandable

"Science presumes that the things and events in the universe occur in consistent patterns that are comprehensible through careful, systematic study. . . Knowledge gained from studying one part of the universe is applicable to other parts."
--taken from www.project2061.org

Systematic observation of examples of weathering leads to knowledge about how the earth has and continues to be shaped.

Lab Activities

The lab activity for today will be a walking tour of campus. During the class hour, you will find places on campus where evidence of weathering can be seen. As your instructor leads you on the tour, think about the following questions.

What does climate have to do with the types of chemical weathering you see on the BYU campus? What might be different at a location on the humid east coast?

How is weathering a part of the rock cycle?

Which building on campus would be most susceptible to weathering? Why?

Lab 7
Sedimentation

Instructional Objectives

1. Define “sedimentation.”
2. Recognize depositional environments.
3. Understand how sediments are lithified into rocks.
4. Relate the role of sedimentation to the rock cycle.

Sample K-5 Science Standards Assessed

National, Grades K-4: Students know that the surface of the earth changes. Some changes are due to slow processes, such as erosion and weathering, and some changes are due to rapid processes, such as landslides, volcanic eruptions, and earthquakes.

Maine, Grades 5-8: Students classify and identify rocks and minerals based on their physical and chemical properties, the compositions, and the processes that formed them.

Texas, Grade K: Students will describe properties of rocks, soils, and water.

Discussion

Can you guess how many years it took to form the famous Navajo Sandstone Formation in Utah’s Zion National Park? These giant towers of consolidated sand grains formed over millions of years as tiny sand grains from ancient sand dunes were carried away by the wind, deposited, and cemented over time. **Sedimentation** is the process by which unconsolidated particles, such a tiny individual sand grains, are transported and eventually deposited. The unconsolidated particles are known as **sediment**. Most sediment deposits are eventually compacted to form sedimentary rocks. Sedimentation can be described in terms of the types of sediments involved and the sedimentary environment, which determines how sediments are transported and deposited.

Types of Sediments. Some sediments are tiny grains of sand. Others include broken pieces of rock rolling along the bottom of a stream, fragmented seashells tossed upon a shoreline, or mud. Sediments may also include plant or animal remains. Based on their origin, sediments are categorized into three main types. Those formed from broken pieces of rock are called **detrital sediments**, while sediments deposited from the remains of plants and animals are called **organic sediments**. **Chemical sediments** are a third type, which form when a solid chemical is precipitated from dissolved material in water. The most familiar example of this process is the evaporation of seawater, which leaves salt behind.

Sedimentary Environments. When geologists look at sedimentary rocks, they can analyze certain features of the rock to determine how the sediments were deposited and make inferences about where they may have originally come from. There are several depositional environments commonly represented in sedimentary rocks, and each type of environment has certain diagnostic characteristics.

1. Continental Environments.

    A. **Rivers and lakes**. Swiftly moving rivers can carry large coarse-grained sediments and deposit them as cross-bedded structures. They also produce ripple patterns that indicate the flow direction of the current. In lakes and places where a river flows slowly, sediments have a chance to settle. During settling, large particles settle first and the smallest particles settle last—so the sedimentary features become characterized by layers of varying particle size.

    B. **Glacial environments**. Glaciers transport but do not sort materials. The resulting deposit is an unsorted accumulation of angular boulders, gravel, sand, and silt.

    C. **Eolian** environments. Wind is an effective sorting agent and will selectively transport sand and dust, leaving gravel behind. Windblown sand commonly accumulates in dunes, characterized by well-sorted grains. The dominant sedimentary structure in eolian environments is cross-bedding.

    D. **Alluvial fans**. These are fan-shaped stream deposits that accumulate on mountain fronts in dry basins. Poorly sorted sands and gravel characterize alluvial fans.

2. Shoreline Environments.

    A. **Deltas**. Deltas are accumulations of mud, silt, and sand that are deposited at the mouths of rivers as water empties into the ocean or a lake.

    B. **Beaches**. Beaches are shoreline accumulations of sand.

    C. **Lagoons**. Lagoons are elongate bodies of seawater located between the mainland and barrier islands or reefs. Low wave energy permits the deposition of mud.

    E. **Tidal Flats**. Tidal flats are shoreline areas that are covered with water at high tide and uncovered at low tide. The predominant sediment is silt.

3. Marine Environments.

    A. **Shallow-marine**. Shallow seas are widespread along the continental margins. Sediments deposited in shallow-marine waters form extensive layers of well-sorted sand, shale, and limestone that typically occur in cyclical sequence as a result of shifting environments due to changes in sea level. The shallow-marine environment extends from the shore to the edges of the continental shelf.

    B. **Organic Reefs**. Reefs are structures composed of the shells and secretions of marine organisms. Corals and algae build the reef framework. These organisms produce highly fossiliferous limestones. Reefs grow in warm, shallow water.

    C. **Deep-marine**. The deep ocean adjacent to the continents receives a considerable amount of sediment transported from the continental margins by turbidity currents. This environment produces thick sections of sand and silt-sized layers representing short periods of time separated by thin sections of very fine-grained sediment representing long periods of deposition.

Lab Activities

This lab will allow you to work in groups and use your creativity to develop short demonstrations on sedimentation. You will work in 4 groups. Each group will be given approximately 25 to 30 minutes to develop their demonstration. They will then each take 2 to 3 minutes to communicate their ideas to the rest of the class.

Group 1. Wind and erosion

Materials Needed:

- Fine-grained soil
- Gravel
- Sand
- Large tray
- Large balloon

Activity: **Design** a short demonstration to show the effect of wind on the transport of materials. **Share** your demonstration with the class and **relate** your class discussion to a comparison of how particles of different sizes are transported by wind. **Hypothesize** about the size of the particles that would make up a sedimentary rock formed by wind transport.

Group 2. Water and sedimentation

Materials Needed:

- Gravel
- Sand
- Fine-grained soil
- Large tray
- Water squirt bottle

Activity: **Design** a short demonstration to show the effect of flowing water on particle transport. **Share** your demonstration with the class and **relate** your discussion to a comparison of how particle size affects movement by water. **Hypothesize** what would happen if the water flowed over the materials at both slight and steep slopes (but you only need to demonstrate one case).

SCIENCE AS INQUIRY
Focus on the National Science Education Standards

Two important skills for doing scientific inquiry are the ability to:

Plan and conduct a simple investigation

Communicate investigations and explanations.

This lab asks you to design your own investigation and then communicate your explanations to others. Part of the nature of science is communicating your results to other scientists. The National Standards state that K-4 students should understand that **"Scientists make the results of their investigations public; they describe the investigations in ways that enable others to repeat the investigations."**

Group 3. Settling Patterns

Materials Needed: Gravel
Light-colored sand
Clay
Large jar with tight-fitting lid
Water

Activity: **Design** a short demonstration to show how particles of different sizes settle out of moving water. **Share** your demonstration with the class and **relate** your discussion to a comparison of the rate at which particles of different sizes settle. Make a **hypothesis** about settling rate and the speed at which the water (such as in a river) is flowing.

Group 4. Making inferences about sedimentary environments

Materials Needed: Pictures showing 3 different sedimentary environments

Activity: **Study** the 3 pictures and **make inferences** about the sedimentary environment that created each unique landscape feature. **Share** your thoughts with the class and **relate** your discussion to how wind, moving water, and ice act differently in different environments to create unique landscape features.

Lab 8
Sedimentary Rocks

Instructional Objectives

1. Know methods that can be used to identify common sedimentary rocks.
2. Use diagnostic properties to identify common sedimentary rocks.
3. Relate the affect of environment on sedimentary rock properties.

Sample K-5 Science Standards Assessed

National, Grades K-4: Students should develop an understanding of the properties of earth materials.

Maine, Grades 5-8: Students classify and identify rocks and minerals based on their physical and chemical properties, the compositions, and the processes that formed them.

Texas, Grade K: Students will describe properties of rocks, soils, and water.

Discussion

Sedimentary rocks are classified according to their sediment type. Detrital sediments form rocks classified as **clastic**, while organic and chemical sediments form chemical, or **non-clastic**, rocks. Note that the term chemical is used to describe both a sediment and a sedimentary rock type.

A common clastic sedimentary rock is shale, the most abundant of all sedimentary rocks. Shale forms when mud and clay harden. Because the clay sediments are extremely small, they settle out slowly. In fact, shale formations can take about 5 million years to form.

Sandstone, another clastic sedimentary rock, is composed mainly of cemented grains of sand. Its main mineral constituent is quartz, and it is known to be very hard and abrasive. Another common clastic rock, conglomerate, looks like a mixture of different-sized rounded pebbles cemented together. Conglomerate forms when rapidly moving water drops pebbles into sand at the bottom of a river or stream. Over time, the pebbles and sand become cemented together.

The most common chemical sedimentary rock is limestone. Most limestone rocks are organic — that is, they develop from the remains of organisms. Much limestone is made up of marine animals and contains pieces of shells, corals, etc. Another chemical sedimentary rock is coal, which is often found in layers with other sedimentary rocks. As plant remains are deposited in layers and slowly alter into carbon over millions of years, they form coal.

Sedimentary rocks often preserve some of the features of the depositional process. For example, little waves or ripple marks may develop in the sand on a beach. The rock that forms from that sand may have rippled lines. Another common feature is mud cracks, which develop when the sediment at the bottom of a river or stream goes through cycles of wetting and drying.

Sometimes sedimentary rocks contain features called **concretions**, hard, rounded objects that become enclosed in the rock. A special type of concretion is a geode, whose hollow interior is lined with crystals. Sedimentary rocks are also the source of most fossils. Because older rocks contain simpler fossils, the age of a rock can be estimated by looking at any fossils in it. The color of sedimentary rock is another clue to the chemical composition of the sediments from which it formed. The bands of red and pink rocks in the Grand Canyon, for example, come from iron-bearing minerals such as hematite.

Sedimentary rocks cover almost the entire ocean floor and about three-fourths of Earth's surface land area. Like igneous rocks, sedimentary rocks may undergo changes that transform them into new, metamorphic rocks. Along with igneous and metamorphic rocks, sedimentary rocks are part of the rock cycle. The processes involved in the formation of sedimentary rocks are:

1. Physical and chemical weathering
2. Transport of these weathered products by water, wind, gravity, or ice
3. Deposition of the material, and
4. Compaction and/or cementation of sediment into rock.

Lab Activities

Geologists often use clues in rocks to make inferences about past geologic events. For example, ripple marks in a bed of sedimentary rocks may indicate that running water once influenced the area. Or large silt deposits are indications that a glacier may have once covered an area.

For this lab activity, you will examine some samples of common sedimentary rocks and make observations about their properties. You will then use your observations to make inferences about the sedimentary environment in which each sample was formed and make some hypotheses about any past geologic activities (like running water, wind, glaciations, or evaporation) that may have contributed to the formation of each sample.

Materials Needed: Samples of common sedimentary rocks
Dropper bottles with 10% HCl

Activity:

1. Record your observations for each rock sample (color, grain size, texture, presence of fossils, unique features, etc.)

2. Divide the rock samples into clastic and nonclastic categories.

3. Decide if any of the samples have features that give you clues as to their environment of formation.

4. Use Table 10.1 to assign a name to each rock, based on its properties.

5. Describe a reasonable sedimentary environment for each rock.

Table 10.1 Diagnostic Properties of Some Common Sedimentary Rocks

Rock Name	TEXTURE	REMARKS
Conglomerate	Coarse grained with particles over 2 mm in size	Rounded fragments of any rock type. Members of the quartz family are most common. May be any color
Sandstone	Medium grained with particles 1/16 to 2 mm in size	Cemented sand grains with quartz as the most common mineral. Color depends on cementing agent and color of sand grains.
Siltstone	Fine grained with 1/256 to 1/16 mm in size	Same composition as sandstone, but finer grained. Individual grains can be barely seen without magnification.
Shale	Very fine grained with particles less than 1/256 mm in size	Same composition as sandstone and siltstone but is composed of very fine-grained clay particles. May contain fossils. Color varies.
Limestone	Massive—has no special form or shape	Main mineral is calcite and effervesces freely. May be any color but is most commonly tan to black. If fossils are present, it is called fossiliferous limestone.
Chalk	Fine grained and soft	Chalk is made of the hard parts of microscopic marine organisms. Effervesces in acid.
Travertine	Banded calcite	Deposited when groundwater containing calcite evaporates. Common as stalactites and stalagmites in caves. Effervesces in acid.
Dolomite	Massive	Main mineral is dolomite. Looks like limestone, but can be distinguished by the acid test.
Chert	Massive	Sedimentary quartz
Rock Salt	Massive	Sedimentary form of halite. Deposited when large bodies of water dry up
Rock Gypsum	Massive	Sedimentary form of gypsum. Has a hardness of 2
Coal	Massive	Compressed plant remains. Black color.

Lab 9
Metamorphic Rocks

Instructional Objectives

1. Define “metamorphic rock.”
2. Explain the difference between contact and regional metamorphism.
3. Recognize samples of metamorphic rocks as either foliated or non-foliated.
4. Relate properties of metamorphic rocks to their conditions of formation.
5. Compare metamorphic rocks to their parent rocks.

Sample K-5 Science Standards Assessed

National, Grades K-4: Students should develop an understanding of the properties of earth materials.

New York, Grades 5-8: Students will use a diagram of the rock cycle to determine the geologic processes that led to the formation of a specific rock type.

Utah, Grade 4: Students will explain the rock cycle concept.

Discussion

What does it mean to be “rock solid?” The phrase is used to describe something that cannot easily be changed. Metamorphic rocks are rocks that have been changed within the Earth—but only by environments where pressure and/or heat are intense. These extreme conditions are present deep inside the Earth. *During metamorphic processes the minerals in the rock do not melt. They recrystallize while in the solid state.*

There are several types of **metamorphism**, the process by which rocks change into new rocks. These types are divided into two general categories, contact metamorphism and regional metamorphism.

Contact Metamorphism occurs when a rock is exposed to hot magma inside the Earth. The intense heat of the magma alters the rock, often causing its minerals to recrystallize. The new rock has different or larger mineral crystals than the older rock. Sometimes the hot magma will even introduce new chemicals and modify the composition of the original rock. The area of rock affected by contact metamorphism is appropriately known as the **baked zone**.

Regional Metamorphism, on the other hand, occurs during the formation of mountain ranges. As tectonic plates collide and converge, intense heat and pressure deforms and alters sedimentary and igneous rocks already buried in the Earth. The mountain ranges of east Greenland are an example of where this has taken place. Often, folds or curves in the rocks indicate the direction of the intense pressure.

Whether metamorphic rocks are formed by contact with hot magma or by heat and pressure from colliding plates in the Earth, the result is that mineral crystals in the original rock are transformed. The new rock is classified into two basic types: foliated and non-foliated.

Foliated metamorphic rocks are those in which the minerals have been flattened and pushed down into parallel layers. In other words, the minerals have been **realigned** in response to directional pressure. The bands in foliated metamorphic rock can look like pages in a book. Slate, one of the most common foliated metamorphic rocks, splits easily into thin slabs. Another example of a foliated metamorphic rock is schist.

A third example of a foliated metamorphic rock is gneiss (pronounced "nice"), a coarse-grained rock with a rough feel. It is characterized by bands of light and dark minerals. Although gneiss often looks much like schist, it does not split as easily into thin slabs. Of the three foliated rocks discussed here, gneiss results from the most intense metamorphism.

Non-foliated metamorphic rocks do not display layers. Rather, they are massive structures with no obvious banding. A good example of non-foliated rock is quartzite, the smooth-textured, metamorphosed form of the mineral quartz. A coarse-textured non-foliated rock is marble. Anthracite, or hard coal, is a non-foliated rock that forms when intense pressure drives gases out of soft coal, causing it to harden.

Note that a parent rock may metamorphose into several different metamorphic rocks. For example, shale (a sedimentary rock) can be transformed into slate, schist, or gneiss, depending on the degree of metamorphism. The greater the pressure and heat, the more likely the shale will change into gneiss.

The rock cycle does not end with a metamorphic rock. Processes of change are always at work, and a metamorphic rock can be broken or eroded into sediment, or melted and reformed as an igneous rock. The environmental forces that drive the rock cycle are responsible for the ever-changing face of Earth's landscape.

Lab Activities

In this lab, you will simulate a metamorphic process that causes mineral crystals within a rock to become realigned. You will then learn how to identify some common metamorphic rock samples.

A. A Simulated Metamorphic Process (Suggested Class Time: 15 minutes)

Work in 3 to 4 groups for this activity. Each group will perform the same activity.

Materials Needed:

- A Kudos® bar, with chocolate chips or candy pieces if desired
- 2 pieces of plywood, 5 by 9 inches
- 2 pieces of wax paper
- 3 large clamps
- Razor blade
- Ruler

Activity:

1. Unwrap the Kudos bar and record its dimensions.

2. Using the single edged razor blade, cut off one end of the bar and carefully observe and sketch the grain orientation (arrangement and position of the particles with respect to each other) of the granola bar. If your bar has a chocolate coating, note its thickness and degree of uniformity. Sketch what you see below.

3. Place a sheet of wax paper on one of the pieces of plywood, place the bar in the center of the waxed paper, cover it with the second sheet of waxed paper and place the second piece of plywood on top; be certain that the edges of the plywood are lined up so that one piece of plywood sits directly above the other.

4. Tighten the C clamps until the plywood/granola "sandwich" just fits between the jaws of the clamps. Place 2 clamps along one of the long sides of the plywood, one near each end. Place the third clamp on the opposite side an equal distance between the first two. Tighten each clamp just enough to hold the bar in place.

5. Starting with one clamp, tighten each clamp in sequence, one turn at a time, until none of the clamps can be turned any tighter BY HAND. Do not tighten the clamps beyond what you can do with your hands.

6. Loosen the clamps and observe changes that have been made in your granola bar. Record your observations below.

B. Identifying Common Metamorphic Rocks (Suggested Class Time: 25 minutes)

Materials Needed: Samples of common metamorphic rocks

Activity:

1. Record your observations of each rock sample (color, unique features, grain size, banding, etc.)

2. Classify your samples as foliated or nonfoliated.

3. Record any similarities you notice to some of the sedimentary rocks from the previous lab.

4. Use your observations and Table 11.1 to assign a name to each rock.

Initial Kudos Bar Observations

Final Kudos Bar Observations

Table 11.1 Properties of Common Metamorphic Rocks

MINERAL COMPOSITION OF ROCK	TEXTURE OF ROCK	GRAIN SIZE	SPECIES NAME
Clays, mica family minerals	Foliated	Microscopic, not visible even with hand lens	SLATE
Clays, Mica family minerals	Foliated	Fine-grained, some visible with hand lens	PHYLLITE
Mica family minerals, quartz, garnet	Foliated	Medium-grained to slightly coarse	SCHIST
Quartz, micas, feldspars, amphiboles, and pyroxenes	Foliated	Coarse, light and dark interlayered bands	GNEISS
Amphiboles, usually hornblende, and plagioclase feldspar	Foliated	Coarse, banded	BANDED AMPHIBOLITE
Quartz	Homogenous	Fine to medium	QUARTZITE
Calcite	Varies	Microscopic to medium	MARBLE
Amphibole, usually hornblende, and plagioclase feldspar	Non-foliated	Fine to medium	AMPHIBOLITE
Rounded rock fragments in groundmass	Non-foliated	Coarse	METACONGLOMERATE

<u>Questions for Thought</u>

Consider the sample of granite you learned about in the Igneous Rocks Lab. Granite metamorphoses to become gneiss. Describe the processes you think might have been involved in this change.

Compare slate to the sedimentary rock shale. They look much alike. What would be a good way to distinguish between them in the field?

Schist can eventually metamorphose to gneiss if conditions are right. What conditions do you think would cause this change?

Lab 10
Volcanoes

Instructional Objectives

1. Identify the places where volcanoes are most likely to occur.
2. Identify the causes of volcanic eruptions.
3. State the relationship between volcanic activity and related geologic features.

Sample K-5 Science Standards Assessed

National, Grades K-4: Students know that the surface of the earth changes. Some changes are due to slow processes, such as erosion and weathering, and some changes are due to rapid processes, such as landslides, volcanic eruptions, and earthquakes.

New York, Grades K-4: Students understand that extreme natural events (floods, fires, earthquakes, volcanic eruptions, hurricanes, tornadoes, and other severe storms) can have positive or negative impacts on living things.

Utah, Grade 3: Students will describe the relationship between active volcanoes and related geological features.

Discussion

Volcanoes are openings in the earth's crust through which magma erupts and is forced onto the surface as lava. Recall from the Plate Tectonics lab that most volcanoes occur along subduction zones where dense oceanic plates are being subducted under lighter continental plates. But volcanoes may also form at divergent plate boundaries where resulting cracks open up in the earth's crust. Or volcanoes are sometimes found in the middle of a plate, at places known as "hot spots." Volcanoes have different eruptive properties depending on the conditions of their formation:

1.**Subduction zones**. Part of the subducted oceanic plate is melted as it sinks; it later rises through the upper mantle and crust as magma, and sometimes reaches the surface. In a case where magma erupts over a subduction zone, the resulting volcano is known as a **composite volcano**. Composite volcanoes are common in regions such as the Pacific Northwest and the Andes Mountains. Subduction zones foster explosive volcanic eruptions, known as **pyroclastic** eruptions. They produce thick rhyolitic and andesitic lavas as well as ash flow deposits. Pyroclastic eruptions are usually accompanied by several life-threatening effects, which include pyroclastic flows of hot material moving at a high speed, and **lahars**, or volcanic mudflows.

2.**Divergent plate boundaries**. At divergent plate boundaries, where crustal plates are pulling apart from each other, volcanoes are characterized by nonexplosive eruptions. They are usually associated with basaltic lava, which is very hot and highly fluid. The runny basaltic lava flows quickly to cover a large area and form relatively flat cones, known as shield volcanoes. Sometimes the mass of the solidified lava causes the

Focus on the Nature of Science: Science is a Complex Social Activity

Science and the values of society are inevitably connected. Scientists seek to explain the natural world and are often most actively involved in those questions that affect the health, livelihood, and progression of society.

Volcanoes have long been threats to human life. Scientists who study volcanoes seek to find ways of reducing a volcano's threat. They do this by focusing on ways that they can come to predict when and how volcanoes will erupt.

cone of the volcano to collapse. When this happens, the volcano can become “plugged,” and the erupting magma is diverted laterally, producing a flank eruption from the side of the volcano. Hawaii’s K’ilauea and Mauna Loa are examples of shield volcanoes.

3.**Hot Spots**. Hot spots are localized spots on the interior of a crustal plate where plumes of magma break through to the surface. Most hot spots are under the ocean, though a few others exist under continental crust, e.g., in Northern Africa and in Yellowstone National Park. Oceanic hot spots are responsible for the development of the Hawaiian Islands. Hot spot eruptions may be explosive or nonexplosive.

Magmas vary in their chemical composition. High-silica felsic magmas crystallize (form igneous rocks) at low temperatures and tend to be highly viscous (thick and slow flowing). Conversely, mafic magmas, which contain much less silica, crystallize only at very high temperatures, and they flow easily. Mafic magmas are more likely to rise to the surface than high-silica felsic magmas. For this reason, a great build-up of pressure is necessary to cause the slow-flowing felsic magmas to rise to the surface, and when they do erupt, the eruption is explosive.

Almost all volcanoes have the same major components. They have a mountain, or **volcanic cone**, built up of the product of a series of eruptions. For composite volcanoes, the cone is made of alternating layers of pyroclastic materials and solidified lava. Volcanoes also have a **volcanic crater**, which is the bowl-shaped depression from which materials escape at the top.

Lab Activities

For today’s lab, you get to be a volcanologist, someone who studies volcanoes and helps civic leaders make decisions about volcano hazards.

Your instructor will give you some information about current or recent volcanic activity. The information will come from the US Geological Survey’s Volcano Hazard Program. Their website, http://volcanoes.usgs.gov/, has up-to-date information on volcanic activity around the world.

Work in 3 to 4 groups and answer the following questions about the volcano you are assigned by your instructor. As you work, imagine that you have been hired by the local government to predict how safe it is for the residents around the volcano. What will you recommend?

Activity

State each of the following for the volcano you have been assigned.

Name of volcano

Geographic location Name of nearest city (include nearest major city if small towns are closest)

Distance to nearest city (include nearest major city if small towns are closest)

Population of nearest city (include nearest major city if small towns are closest)

Dates of most recent eruptions

Type of volcano (shield, cinder cone, composite or strato volcano)

Composition of the igneous rock or magma (andesitic, basaltic, etc.)

Temperature (if available)

Gas content (high, low, etc.), and give gases if listed

Types of material ejected (lava, ash, volcanic bombs, etc.)

Other events associated with the recent eruptions (earthquakes, mudflows, lahars, nuee ardentes, floods, etc.)

Major hazards to humans living in the area

Speculate on what you would do if you were in charge of volcanic hazard mitigation in the area of your volcano.

Lab 9
Plate Tectonics

Instructional Objectives

1. Recognize that the earth's lithosphere is composed of plates that move in response to the flow of the asthenosphere below them.
2. Give evidence to support the theory of plate tectonics.
3. Describe the relationship between much of the earth's large-scale geologic activity, such as earthquakes and volcanoes, and the location of plate boundaries.
4. Describe different ways that plates move relative to each other, such as divergence, convergence, and transform motion.

Sample K-5 Science Standards Assessed

Maine, Grades 3-4: Students describe the change in position of the continents over time.

Maryland, Grades 4-5: Students explain that Earth's surface is the result of a combination of constructive and destructive forces.

South Dakota, Grade 3: Students will model the way natural forces shape the surface of the earth.

South Dakota, Grade 4: Students will describe geologic features of the ocean floor.

Discovering Plate Boundaries

Four Map Version

Student Handout

You have been (or will be) assigned to one of four Scientific Specialties and to one of ten Plates or Plate Groupings.

The Scientific Specialties are:

A. Seismology
B. Volcanology
C. Geography
D. Geochronology

The Plates or Plate Groupings are:

1. North American Plate
2. Pacific Plate
3. African Plate
4. South American Plate
5. Eurasian Plate
6. Cocos/Nazca/Caribbean Plates
7. Australian Plate
8. Antarctic Plate
9. Indian Plate
10. Arabian Plate

Each Scientific Specialty group has been provided a world map showing data relevant to locating plate boundaries and understanding plate boundary processes. Each student will be provided two Plate Boundary Maps. You will mark these as described below and turn them in at the end of the exercise. There are a number of colored pencils available in the room for your use.

Period 1: Assemble in your Scientific Specialty groups with your group's map

Task 1. Look at your group's map and talk about what you see. What you look for will vary with data type. For the point data (volcanoes and earthquakes) you are looking for distribution patterns. For surface data (topography and seafloor age) you are looking for where the surface is high and where it is low, where it is old and where it is young. Work as a group. Let everyone talk about what they see. During this period concentrate on the whole world, not just your assigned plate (if you know what it is).

Task 2 . Now focus your attention on the plate boundaries. Identify the nature of your data near the plate boundaries. Is it high or low, symmetric or asymmetric, missing or not missing, varying along the boundary or constant along the boundary, and etc. As a group, classify the plate boundaries based on your observations of your group's data. Restrict yourselves to about 4-5 boundary types. At this point, do not try to explain the data; just observe!

Task 3 . Assign a colored pencil color to each boundary type in your classification scheme. Color your first Plate Boundary Map to locate your group's boundary types. If the data are asymmetric at a particular boundary type, devise a way of indicating that on your plate boundary map. Each person should mark the boundary types identified by the group on their own map. Each person should write down descriptions of the group's plate boundary classifications on the back of their map. These maps and descriptions will be turned in at the end of the exercise.

Period 2: Assemble in your Plate groups

Task 1. Each person should make a brief presentation to the rest of their group about their Scientific Specialty's data and classification scheme. Your group may move to each map in turn while doing this or you may have smaller maps for each group to use.

Task 2. Compare the classifications of boundary type for your plate based on each type of data. Are there common extents (along the boundaries) between the different classifications? Can your plate group come up with a new classification scheme that now includes data from all four Scientific Specialties? As above, assign a color to each of your plate boundary types. If a boundary is asymmetric, be sure to devise a way to represent the asymmetry. Mark the boundaries of your plate or plate grouping using your color scheme on your second Plate Boundary Map. Also write a description of the plate boundary classes you have used. The map and description should be turned in at the end of the exercise.

Period 3: Whole Class Discussion

One student from each Plate Group should make a presentation to the class. They should talk about their group's plate boundary classification scheme and how they classify the boundaries of their plate. You will be given an overhead transparency of the Plate Boundary Map and some transparency markers to prepare for the presentation.

The instructor will conclude the exercise by summarizing the students' observations and placing them in the context of accepted plate boundary types and plate boundary processes.

To be turned in by each student after Period 3

1. Plate Boundary Map with classified using data from your assigned scientific specialty. Descriptions of the plate boundary classifications devised by your specialty group should be on the back of the map.
2. Map with your assigned plate's boundaries classified using data from all four scientific specialties. Descriptions of the plate boundary classifications devised by your plate group should be on the back of the map.