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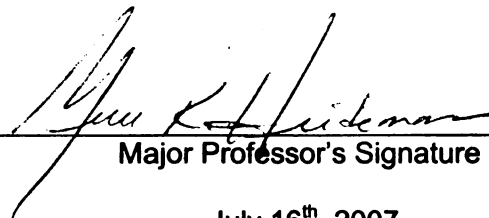
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TEACHING A UNIT ON ROCKS AND MINERALS
IN AN EARTH SCIENCE CLASSROOM

By

Michael R. Bause

A THESIS

Submitted to
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ABSTRACT

TEACHING A UNIT ON ROCKS AND MINERALS IN AN EARTH SCIENCE CLASSROOM

By

Michael R. Bause

Rocks and minerals are important components of the Earth Science curriculum. Rocks and minerals also play an important role in the students' daily lives. They need to understand not only the economic impact that rocks and minerals have on their lives, but also the environment of formation of rocks and minerals. This thesis contains a collection of demonstrations and activities that enabled my students to learn the concepts needed in order to be successful in an Earth Science classroom. The findings of this investigation are based on pre- and post-test assessments. A significant increase in student achievement suggests that after students are actively engaged in a variety of critical thinking, hands-on, cooperative learning activities, their understanding of rocks and minerals will increase.

DEDICATION

This thesis is dedicated to my friends and family who have been exceptionally supportive throughout this entire process. Thank you to my parents, who have always believed in my abilities without question. Thanks to my son, Sean, for teaching me that everyday is a blessing and worthy of waking with a giggle, a jump on the bed and a bottle of a favorite beverage, milk in his case. Lastly, my most heartfelt thank you goes to my wife, Kelly, to whom I owe the leaping delight that quickens my senses. Without her assistance, assurance, and encouragement, I would surely still be contemplating how to begin.

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To the SME 899 Summer 2006 class, specifically Andy Moore and Jim Preston, thank you for helping me keep my head above water or at the very least not allowing me to sink alone.

Finally, I would like to acknowledge the Towsley Foundation for supporting our efforts to improve education.

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INTRODUCTION

I. Statement of Problem and Literature Review

As an Earth Science teacher, the purpose of my work is to teach this curriculum in a manner such that the student will master the material. Teaching rocks and minerals to ninth graders of various abilities has proven to be a challenge. It is not easy to motivate and hold the interest of all students since there is such a wide range of academic backgrounds, ability levels and interests. In addition, another problem I have had teaching this unit has been to engage the students in meaningful hands-on laboratory investigations that stimulate problem solving skills. Historically, my laboratory investigations have simply focused on identification of rocks and minerals without much investigation or deep thought. As a consequence of this, my students typically become bored with the unit resulting in poorer exam scores and less enthusiasm towards material.

To achieve my goal of adding excitement to the unit and limiting basic identification laboratory assignments, I studied learning strategies that help students ascertain the necessary skills to be successful inside the classroom and outside of school. I focused my research on cooperative

learning skills, where students "interact in purposefully structured heterogeneous groups to support the learning of oneself and with others in the same group" (Jinks, et al, 1997). I also focused my research on teaching students critical thinking, problem solving skills. This has been defined as a "higher-order cognitive process that requires the modulation and control of more routine or fundamental skills" (Goldstein & Levin, 1987). In essence, the main idea behind my thesis research was to increase the efficiency of my unit on rocks and minerals by teaching the students critical thinking/problem solving skills and by creating more engaging cooperative-learning based hands-on activities. Some of my sub-goals were to enhance the quality of the written directions on laboratory investigations and to expose the students to various teaching methods and tools to accommodate the various learning styles of students (García-Ros & Pérez-González, 2006), using techniques such as PowerPoint presentations, hands-on laboratory investigations, visuals, student drawings, concept maps, as well as the traditional lecture.

Outside of the classroom, a business scenario for example, strictly relying on individual efforts is insufficient. Cooperative learning activities prepare students for the next steps in their lives, whether a

continuation of their education, beginning a career, or a combination of the two (Jinks, et al, 1997). Today it is well understood that retaining a new concept in the classroom or accomplishing a new task in the business office is more likely to occur when people work together to solve a problem. A study done by Smith (1994) has shown that cooperative learning typically results in both immediate and long term academic benefits, greater personal growth by students, and closer interaction with students by the teacher in the more traditional conceptualization as well as in the new role of teacher facilitator. Cooperative learning prepares students for life after high school. It promotes active learning because students learn more when they discuss solutions with each other about a problem rather than sitting and listening passively. "It motivates, leads to academic gains, fosters respect for diversity and advances language skills" (Mergendollar and Packer, 1989).

Cooperative learning has gained much attention in schools due to its widespread success in improving student achievement. There are several methods of cooperative learning, all focusing on the idea that students work together to learn and are responsible for others' learning as well as their own (Slavin, 1990). The teacher facilitates this process. It is the job of the teacher to

become a guide, a stimulator, and one who encourages, but not one who only lectures or dispenses information. The teacher is a resource person who has numerous materials and necessary information from which students in a cooperative learning setting may gather what is needed to achieve objectives. The teacher is motivated to assist pupils to be creative, to engage in critical thought, and to identify and solve problems (Ediger, 2001).

Family structure is a large contributor to a students' lack of appropriate social skills in a cooperative learning setting. Educators often operate on the assumption that "appropriate social skills and a sense of responsibility have been taught and reinforced throughout the child's home rearing" (Garbarino 1997). Cooperative learning can help teach the students not only the skills necessary to successfully complete a laboratory experience, but also the skills necessary for life after and outside of high school.

Another technique to improve my unit on rocks and minerals was to put into practice more critical thinking questions and problems throughout the unit within laboratory investigations, homework assignments, lectures and even exams. In the past, the debate has been between those who advocate teaching students to memorize the facts of science and those who emphasize hands-on activities that

allow students to explore theory. NAEP, National Assessment of Educational Progress, data supports the benefit of teaching for meaning (using problem solving thinking skills with hands on assignments) rather than memorizing facts. Students tended to score higher on the fourth grade and eighth grade NAEP science tests when they had experienced science instruction centered on projects in which they took a high degree of initiative. Traditional activities, such as completing worksheets and reading primarily from textbooks, seemed to have no positive effect (Wenglinsky 2004).

Teachers who serve as role models in interactions with students and their observations and interpretations of physical events facilitate the development of higher-order cognitive skills (Champagne and Bunce, 1991). Some students, without much practice, may not be able to think through a common problem on a level where they will successfully analyze the problem and conclude. For example, a common misconception students have prior to any Earth Science education is what a rock truly is. Asking students to choose which is more likely to be a rock, a chunk of brick or a piece of polished marble, most students' answer the brick is a rock because it is natural whereas the marble is not natural because it is polished (Driver, et al 1994). In

this particular scenario, the students are not able to deduce that the makeup of marble has not been changed just because it has been polished, whereas, the brick is thought of as natural simply because it is not polished. A student, who has thought through the problem, should be able to deduce that the marble must be the rock simply because it has been altered the least.

Teaching learning skills or strategies cannot substitute for teaching domain-specific content, since one factor frequently relies on the other (Weinstein & Mayer, 1986). More often than not in a science classroom, some specific content needs to be taught within a certain order. The content as well as behaviors and thoughts that are expected to influence the manner in which all information is processed by a learner. However, if the "academic community embeds approaches to critical thinking within the instruction of content, we may be able to teach the approaches implicitly to students" (Marzano, 1992). In other words, teaching the students critical thinking skills will help the student discover the necessary content to move from one unit to the next. Resnick (1987) has found that this can be done by asking students to perform tasks that model specific types of thinking processes. Studies by Brown, Bransford, Ferrara, and Campione (as cited in

Wittrock, 1986) suggested that when students become aware of the cognitive processes they are using, they are able to transfer them more readily to other areas of their learning.

Exploring ways to improve students' ability to think critically is in step with the current reform movement in education. Directing the attention of students to purposefully question activities may result in forcing them to confront misconceptions with which they have grown comfortable so that in resolving their discrepancies, more meaningful learning may result (Arburn & Bethel, 1999).

In summary, using cooperative learning, I expect to engage my students in the laboratory investigations so that they feel important in their part of the investigation and that they understand the material in greater depth than just identifying common rocks and minerals. I also hope that the abundance of practice of critical thinking questions will allow the students' to grasp the ability to provide more depth in their thought process.

II. Demographics

The high school students studied were mostly ninth graders with some tenth through twelfth graders. The school is located in Oakland County, which is in the Detroit

metropolitan area. It is one of three high schools within the district. Approximately 1,380 students were enrolled during the 2006-2007 school year. Ninety-six percent of the 2005-2006 graduating seniors attended a two or four year degree program. In 2006, students took 379 AP exams with 75% scoring a three or better. A score of three is considered passing while a five is considered the highest possible. The AP tests for 2007 were not available for this research. The results of the 2005-2006 ACT exams were based on 271 students and the average score was a 23.9. Fifty-six students took the SAT and received an average score of 1783. There were two National Merit Semi-finalists and 2 National Merit Commended students.

The student body is considered multicultural. The students represent a variety of ethnic, religious and cultural backgrounds including, but not limited to, Caucasian, Jewish, African-American, Chaldean, Albanian, Arabic, and Japanese. Within our district over eighty different languages are spoken. In terms of economic status the community is considered upper middle class.

The students within this research were from my Geophysical Science and my General Geophysical Science classes. The students who take Geophysical Science their freshmen year are historically, but not limited to,

students that obtained a C or less in their eighth grade science class. Those students receiving higher than a C take biology their freshmen year and skip geophysical science altogether. Students enrolled in the General Geophysical Science class are students who have an Individual Education Plan (IEP) requiring more staff support, modifications and other special requirements. In this class there are two additional teachers: a bilingual co-teacher and a Special Education teacher. Out of the 92 students within the three sections of Geophysical Science classes and the one General Geophysical class, 80 of the students participated in this study.

III. Scientific Background

Mineralogy is the science of minerals. This includes their crystallography, chemical compositions, physical properties, identification, and classification. The definition of a mineral is a naturally occurring, inorganic, crystalline solid with a definite chemical composition. Much can be learned about minerals by examining each portion of the definition.

Though nearly all scientific definitions include "naturally occurring" as necessary to meet the requirements of a mineral, there are varying interpretations of its

specific meaning. In the traditional interpretation, naturally occurring means that a particular specimen must have been formed by natural processes, without any interference from humans. Lab-grown diamonds (man-made), as opposed to naturally occurring diamonds, are not imitations, a substance designed to look like another, neither are they fakes, substitute substances used to deceive, but are actually real diamonds, with all of the chemical and physical properties of naturally occurring diamonds. However, since they are lab grown and assisted by humans, they cannot be labeled as a mineral even though they meet every other standard.

A mineral must also be, by scientific definition, an inorganic substance. This means that it must not be a hydrocarbon, a group of chemical substances rich in carbon, hydrogen, and oxygen. Hydrocarbons are chemical substances which make up most living tissue or once living material. Amber, valued for its aesthetic appeal in jewelry, coal and petroleum, both fossil fuels, are all naturally occurring substances, but are excluded from the mineral designation because they are organic materials.

The scientific definition also requires that the material be a crystalline solid. Crystalline means that the atoms making up a substance are arranged in a definite

pattern, making an orderly, three-dimensional network. The crystalline nature of minerals results in rather consistent physical properties in all specimens of the same material, which allows mineralogists to identify them. Noncrystalline solids do occur in nature. Opal, a semiprecious gem, is a naturally occurring noncrystalline solid (Chesterman, 1998). Obsidian, volcanic glass, is formed from the cooling of lava which is so thick and viscous that the atoms cannot migrate within it to arrange themselves into crystalline patterns to make crystals.

The composition of a mineral must be consistent enough so that a chemical formula may be written for it. Quartz, for example, consists of oxygen and silicon in a 2:1 ratio, so the formula SiO_2 is written for quartz.

Sometimes, the composition of a mineral varies within definite limits due to ionic substitution. Sphalerite, for example, is either ZnS (zinc to sulfur, 1:1 ratio) or FeS (iron to sulfur, 1:1). So the general formula for Sphalerite is $(\text{Zn,Fe})\text{S}$ [the comma within the parenthesis should be read as "or"]. All minerals contain impurities, but these substances occur in small quantities and vary from location to location. Impurities are not shown in the formula for any mineral since their presence is inconsistent.

A large portion of the roughly 4,442 known minerals (Barthelmy 2007) can be identified accurately by observing the physical and chemical properties of a given specimen. The properties depend on the nature of the crystalline structure and the composition of the mineral. Identification of even the most common 200 minerals (about 5% of the known types) requires considerable skill and practice, and depends entirely on accurate observations of the physical properties displayed within the minerals.

When accurate observations are being made, the identification of the mineral can proceed very quickly, usually by the process of elimination. For example, only 50 of the common 200 minerals have a metallic luster (the sheen of its surface or the way a mineral shines in reflected light); only 4 of the 200 have a metallic luster and a hardness less than 2.5 (softer than a finger nail); and only 1 of these 200 has a metallic luster, hardness less than 2.5, and is relatively lightweight (low specific gravity). Thus, observing only three simple physical properties can identify graphite. Identifying a mineral is therefore a narrowing-down process. The number of possibilities narrows each time another critical observation is made.

Petrology is the study of rocks. Rocks are naturally occurring aggregates of minerals and they make up the lithosphere of the Earth. Rocks can be classified in three ways, as an igneous rock, a sedimentary rock and a metamorphic rock, depending entirely on the formation of the rock.

An igneous rock, Latin for fire, is a rock that formed from the cooling and solidification of magma (molten rock). Igneous rocks can be divided into further subgroups by the location from which they cooled. Intrusive igneous rocks consist entirely of crystals large enough to see with the unaided eye. They usually result when the magma cools far enough underground allowing the minerals within to crystallize over longer periods of time resulting in larger crystals. Intrusive igneous rocks are also known as plutonic, which derives from the Greek word pluoton, meaning Pluto and the lower world.

Extrusive igneous rocks either consists of (1) crystals generally too small to see [although a few larger ones may be present]. (2) no crystals at all [glassy], and/or (3) rock fragments produced by volcanic explosions. Extrusive igneous rocks generally result from some form of volcanic activity, where cooling is generally more rapid. Sometimes, magma cools underground but near the surface and

still results in an extrusive texture, small crystals.

Extrusive igneous rocks are also known as volcanic, from the Latin word *volcanus*, meaning Vulcan, god of fire.

Pegmatite is really not a plutonic, intrusive, igneous rock. It is an example of what I would like to declare as another type of igneous rock: *hydrothermal*. The extremely large crystal size and the often very unusual chemical composition both support the notion that pegmatite is crystallized from watery solutions remaining from the last stages of magma crystallization. The pressure of the crystallization fills the magma chamber, and forcefully pushes (injects) the leftovers into fractures and zones of weakness in the surrounding rock. Volatile (liquid & gas) solutions seem to be able to explain the large crystal size, as large amounts of ions must be delivered to the crystal site for the crystal to grow that large. Regular magma seems way too viscous to be able to deliver that much raw material to every crystal site in a relatively short time.

A metamorphic rock, Latin for change in form, forms from an existing rock's exposure to increased temperature, increased pressure, chemically active fluids, or some combination of these. It is important to note that although these rocks are placed under extreme temperatures, they are

not melting. If the rock were to melt, it would then begin the process of becoming an igneous rock by recrystallizing into a solid. This is a brief example of the rock cycle.

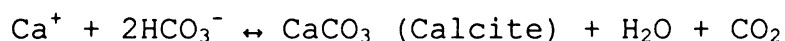
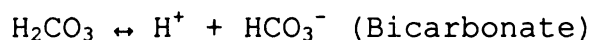
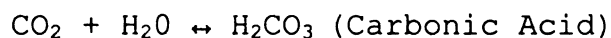
Metamorphic rocks usually form at plate boundaries in connection with mountain building processes and with igneous intrusions. The conditions deep in the Earth vary enough that they can cause minerals different from those which form at the surface to crystallize. For example, limestone, calcium carbonate, can be put through enough pressure to allow the calcite, calcium carbonate, crystals to grow. This process strengthens the rock, makes it denser, and increases the size of the mineral crystals.

Metamorphic rocks can be divided into two more subgroups, regional metamorphism and contact metamorphism. Regional metamorphism occurs when rocks are altered by the action of increased temperature and increased pressure over time. Regional metamorphic rocks occur in the roots of folded mountain belts at convergent plate boundaries. Large quantities of rock are typically metamorphosed simultaneously. Contact metamorphism, on the other hand, occurs when rocks are altered by the action of increased temperature and exposure to chemically active fluids, usually because the rocks were near or in contact with a hot mass of magma. Hot, chemically active fluids are

typically squeezed out of cooling magma and forced into the surrounding rock, resulting in significant chemical change. By comparison, there are considerably smaller quantities of rock that are affected by contact metamorphism.

Sedimentary rocks are formed from the compaction and cementation of the weathered remains of other rocks or of biochemical material. They can be subdivided into three further groups including clastic, organic and chemical. Clastic sedimentary rocks consist of particles of weathered material of varying size which have been deposited and then cemented together. Minerals dissolved within the ground water grow within the pore spaces between each of the particles thereby locking them together. Rocks in this subgroup are generally distinguished by the particle size of the clastic material, i.e. sand within sandstone, clay within shale, pebbles/gravel within conglomerate. Organic sedimentary rocks, also known as bioclastic, rocks that owe their existence to biological processes, such as shells and plant fragments, cemented together. Chemical sedimentary rocks formed when dissolved minerals are chemically precipitated, reforming a solid. They consist of interlocking crystals of various sizes. Many contain fossils due to the precipitated materials accumulating on the bottom of ocean floors and trapping living material.

The process of precipitation is an important one and a very difficult concept for students to visualize. In nature, there is a complex balance in water to form a precipitate. The following process can occur in nature to form a precipitate:



If there is too much CO_2 dissolved in the water, the balance will shift towards the left producing more bicarbonate. If there is less CO_2 in the water, then the paradigm will shift towards the right producing more precipitate. An example of this can occur on a sunny day. When the plants are exposed to increased levels of sunlight, more photosynthesis can occur. Thus, photosynthesis will directly decrease the CO_2 in the water leading to increased precipitation. Other examples include, changing temperature of water and wave and current action within shallow water.

IMPLEMENTATION

I. Introduction

I developed this unit on rocks and minerals at Michigan State University during the summer of 2006. I have taught Earth Science for 5 years and I have never been fully satisfied with my effectiveness in teaching the materials within this unit. The challenge with teaching a unit on rocks and minerals is to edit the identification laboratory investigations and alter them into some truly thought provoking lessons. In addition to the identification laboratory assignments I have added numerous thought-provoking discussions, demonstrations and exploratory laboratory investigations examining the process of rock and mineral formation.

To improve my effectiveness, I significantly revised my original unit which was based on the classroom textbook Earth Science (2002). The new unit is based in 4 parts. Part I: Chemistry Review and Minerals, Part II: Igneous Rocks, Part III: Sedimentary Rocks, and Part IV: Metamorphic Rocks.

Being a member within the Michigan Earth Science Teachers Association (MESTA), I have been able to unofficially observe much of my fellow Earth Science brethren. I have observed that many teach rocks and

minerals in a cut and dry method of teaching the rocks and then doing a lab based on the identification of the rock and/or mineral type. Until recently, I would place my laboratory activities in this category as well. Since the thesis research, all of my labs are hands-on, cooperative learning based and thought provoking investigations.

Table 1 provides a basic outline of this unit including the main idea, order, and time spent for each item.

Table 1: Outline of the Rock and Mineral Unit

* denotes new or improved items to this unit.

TIME TABLE	ACTIVITY	TIME (min)	MAIN IDEA
Week 1: Oct 2 nd	*Pre-Assessment: Minerals	10	Assessment
Week 1	Steel Wool Demo	5	Distinguish between chemical & physical changes
Week 1	*Lab: Chemical & Physical Changes	45	Distinguish between chemical & physical changes
Week 1	Video: Minerals	25	Identify common rock- forming minerals
Week 2: Oct 9 th	*Lab: Crystallization of Thymol Melt	25	Formation of crystal and crystal structure
Week 2	*Lab: Mineral ID Tests	50	Distinguish methods of mineral identification
Week 2	*Lab: Mineral ID #1	45	Distinguish methods of mineral identification and formation
Week 3 Oct 16 th	*Lab: Mineral ID #2	50	Distinguish methods of mineral identification and formation
Week 3	Mineral Review Lab	45	Distinguish methods of mineral identification

Table 1 continued

Week 3	*Post-Assessment: Minerals	90	Unit test
Week 3	*Pre-Assessment: Rock Cycle	10	Assessment
Week 3	*Pre-Assessment: Igneous Rocks	10	Assessment
Week 3	*Computer Lab: Rocks	45	Discriminate between igneous, metamorphic, and sedimentary rocks
Week 4 Oct 23 rd	*Pre-Assessment: Sedimentary Rocks	10	Assessment
Week 4	*Igneous Rock Lab	50	Explain texture and color as indicators of formation
Week 4	*Igneous Fudge	10	How rate of cooling affects crystals size
Week 4	*Pumice Candy	20	How rate of cooling affects crystals size
Week 5 Oct 30 th	*Lab: Making a Sedimentary Rock	25	Size/type of sediment indicates environment of formation
Week 5	*Lab: Making a Precipitate	30 + 1 day	Size/type of sediment indicates environment of formation
Week 5	*Pre-Assessment: Metamorphic Rocks	10	Assessment
Week 5	*Lab: Sedimentary Rocks	45	Size/type of sediment indicates environment of formation
Week 6 Nov 6 th	*Lab: Metamorphic Rocks	45	foliated, nonfoliated indicates type of metamorphism.
Week 6	*Metamorphic Cookie	10	foliated, nonfoliated indicates type of metamorphism.
Week 6	*The Rock'n Brainstorm	75	Discriminate between igneous, metamorphic, and sedimentary rocks
Week 6	Rock Review Lab	35	Discriminate between igneous, metamorphic, and sedimentary rocks
Week 6	*Post-Assessment: Rock-N-Test	90	Unit test

II. Description of Activities and Results

At the beginning of each section, I gave a pre-test to be compared to the students' regular post-test exam (Appendix A). I also gave an all encompassing pre-test of the Rock Cycle (Appendix A-IV). I will speak of these tests more within the Results and Conclusion portion of this thesis.

A. Chemistry Review

I started out the chemistry review portion of my minerals unit by providing a quick pre-assessment of chemistry and minerals (Appendix A-II). Even though my students have had some chemistry in middle school, I find I always have to spend a bit of time reviewing the basics. Since a large portion of the study of rocks and minerals, as well as the entire course, is the ability to distinguish between various chemical processes it is, thus, extremely important the students have a basis to start with. Furthermore, this chemistry unit has to serve as their chemistry background for the entire year. Within my chemistry review unit, the students are examining the differences between the phase changes of matter, chemical and physical changes, and the concepts of expansion and compression.

1. Lab: Physical and Chemical Changes

The first laboratory investigation is titled Chemical and Physical Changes (Appendix B-I), which provides the students with ample examples of chemical and physical changes. I began the lab by asking the students to make a prediction. "Will steel wool burn when introduced to a flame?" A volunteer student lit the wool and it blazed with a very impressive deep red-orange color. I asked the students to record any observations they made. Some near the front were able to smell smoke. After the flames began to subside, I turned the lights back on and the steel wool turned from a grey-metal color to a light blue color. As class, we discussed evidence of this change as a physical or chemical change. Some observations made were, a change in mass, smoke, and fire. The change in mass occurred because an oxidation reaction took place. Oxygen from the surrounding air reacts with the iron in the steel. This is an exothermal reaction producing a beautiful display of color. As a result the remaining material, iron oxide produced by oxidizing steel wool, has changed mass.

Using Iodine crystals, a test tube and a Bunsen burner we watched as the purple Iodine crystals sublimated directly into a gas as the test tube heated up within the flame of the Bunsen burner. The students recorded their

observations and determined whether or not this was a chemical or physical change. Some students struggled with this demonstration. They argued that you could not get the crystals back, but shortly after the gas cooled, you begin to see tiny crystals form on the side of the test tube.

The students then began the investigation portion of the lab. They investigated whether or not cleaning a penny with hot sauce is a chemical or physical change. They investigated whether burning the wick of a candle, melting the wax on a candle, and burning the wax on a candle were chemical or physical changes. The final experiment was called "the Mixture." Each lab table had a large metal container filled with rocks and Kool-aid. The students were asked to write a procedure describing how to separate the rocks, the Kool-aid and the water. They were required to include a description of any physical or chemical changes. In response to this question, many students described the evaporation of water as a chemical process since it has chemicals (red dye) inside of it.

The overall evaluation from the students was 4.3 out of 6. Overall, the students did very well scoring an average of 87% on the lab. Many of the students struggled with the "dirty penny" portion of the investigation. By using the word clean, I think I may have misled the

students into thinking that this was a physical change. I used this confusion as an opportunity to lead a discussion about what really happened. I asked the students if it is indeed a physical change, then how come we used hot sauce to clean the penny and not water? We then decided that we should test the idea. As a class we tried to wash a penny in the sink, to no avail. The students then concluded that although it looks dirty, it must not actually be dirt. We then discussed how oxygen in the air will react with the copper within the penny to form a copper oxide. The acid found within the hot sauce reacts with the copper oxide leaving a shiny surface behind.

B. Minerals

Every lecture within my entire Rock and Mineral unit had a Michigan twist embedded within it. Not only would I discuss the importance of minerals to every human being, but also I would make sure to recognize the importance in Michigan rocks and minerals. With over 300 minerals found in Michigan, the economic importance of minerals needs to be understood at the high school level.

1. Lab: Crystallization of Thymol Melt

In an effort to help the students understand the crystal formation within mineral crystal structures, I

introduced a new lab. It is called the "Crystallization of Thymol Melt" (Appendix B-II). Using stereomicroscopes, watch glass, beaker, water, a hot plate and a small scoop of thymol crystals, students were able to witness firsthand the growth of thymol crystals from melted thymol. My students have historically struggled with the concept of the formation of crystals. It is hard for them to picture what it means for the atoms within the crystal to be regularly ordered, repeating pattern extending in all three spatial dimensions.

Some of the follow up questions within the lab were designed for them to have to think beyond the procedure, the previous demonstrations and the lecture. I asked them the following:

What would happen to the crystal size and shape if we left the crystal formation alone for 24 hours?

Most of the students responded that if there was enough material it would increase in size until the remaining material was used up. Many of the students also included that the shape of the existing crystal would continue as it had been, but it would increase in size as well.

Students enjoyed watching the thymol crystals form. They ranked the lab 4.9 out of 6. The overall score on the lab was 85%. Most of the confusion the students suffered from was due to their lack of understanding of what limits

the growth of a crystal. On a side note, a major downside to using thymol it has an extremely powerful smell of a doctor's office. Students' attention span seemed to be overpowered by the aroma. In the future I might try using acetamide to grow crystals.

2. Mineral Identification Tests

The next lab I developed during my thesis research was designed to teach the students some of the more common properties of minerals. This lab, titled Mineral Identification Tests (Appendix B-III), was designed for students to identify a mineral and their properties rather than me lecturing about the topic.

They received eleven mineral samples and all the necessary tools needed to investigate the various properties of minerals, including streak plates, glass, iron nails, pennies, a copy of the Moh's Hardness scale, and even fingernails (they provide their own). For the mineral property "luster", the students observed and categorized them as either metallic or nonmetallic.

The mineral property "streak" is the color of the mineral in its powdered form. Crushing and powdering a mineral eliminates some of the effects of impurities and structural flaws, and is therefore more diagnostic for some minerals than their color. Some minerals such as pyrite

(fools gold) or hematite (a type of iron-ore common in the Upper Peninsula of Michigan) have completely different color powders than their outer surface colors. This makes them very unique and very easy to identify.

The students performed the streak tests using an unglazed porcelain streak plate and recorded their observations. They found that hematite and pyrite have different color streaks than their outer appearance. Hematite, as an iron ore, has a dark red streak. Due to hematite being an iron oxide, rust should be its color in powdered form. The students also found that quartz is so hard that it scratches the streak plate. We discussed this property and the abundant use of quartz from glass to its aesthetic appeal as a crystal.

The streak test is a natural introduction into the mineral property of hardness, the measurement of the resistance of a mineral from scratching and indicates the bonding strength between atoms within the lattice. The students use everyday objects to help determine the hardness of common minerals. Comparing the hardness of the mineral to objects like their fingernail, pennies, iron nails, and glass can lead them to the minerals' overall hardness. This allowed me to discuss the formation of minerals and how the difference in hardness, or the

difference in the strength of the atomic bonds, allows us to understand the formation of the minerals. For example, a diamond forms near or in the lithospheric portion of the mantle, the top-most portion of the mantle below the crust, where the temperature and pressure are truly extreme. Graphite does not need these conditions to form. It forms closer to the surface under less extreme circumstances.

Another study of the atomic structure of the mineral is the way a mineral breaks. This test identifies whether the mineral cleaves when it breaks or fractures. Cleavage is the tendency of a mineral to break in flat smooth surfaces, whereas, fracture is the tendency to break into seemingly random jagged surfaces. The cause is the atomic bonding structure of the mineral itself.

The students ranked this lab fairly poorly with it earning a 3.9 out of 6. On the upside, the students did quite well with the lab mostly due to the lack of critical thinking questions, earning an average of 91%. This lab allowed the students to learn the material on their own without a lengthy lecture which is why I will use this lab again, but alter it to make it more interesting. For example, they were using very common minerals. I could change the minerals to some that are far less common, but still not overly valuable, like corundum, pyrite, fools

gold, and sulfur (which smells bad and the students love it). I could also make it a little less cumbersome by decreasing the amount of minerals they test. Performing the same test eleven times may not be necessary to accurately learn each identification test.

3. Mineral Identification Lab #1

In Mineral Identification Lab #1 (Appendix B-IV), students used the information gathered from the Mineral Identification Tests laboratory investigation to follow a dichotomous chart to determine the accurate identification of each of the eleven minerals. Despite my goal to limit the amount of identification labs, I included this in my unit because it provided the students a dual opportunity to use a dichotomous chart and to double check their work from the Mineral Identification Tests Lab. It also provided me an opportunity to ask some in-depth, critical thinking questions. For example, I had them solve the following problem:

The mineral calcite and the mineral quartz have a lot of similarities including color, density, luster and streak. Using what you have discovered about these two minerals, explain at the atomic level why quartz can scratch glass and calcite can only scratch the human fingernail.

Since this was the first of many thought provoking questions, my students seemed a little dismayed by the problem and how to solve it. At this stage they have not

had much experience with questions that force them to take their knowledge to the next level. They are used to being able to search through notes and/or their textbook to find the answer with very limited difficulty. In response, most students simply stated that quartz is harder than calcite, but they did not describe the reason why this is true.

Although I anticipated better results on this question, it did provide me with an opportunity to clarify my expectations on these questions. As an upshot of this discussion, future questions of this manner were handled with far more care. The lab was ranked 4.1 out of 6 and the students earned an average score of 79%. I intend to use this lab again in the future with the possibility of limiting the amount of minerals so that I have more time in class to go over the lab.

4. Mineral Identification Lab #2

I followed this lab with another identification lab, Mineral Identification Lab #2 (Appendix B-V). In this lab, students randomly chose two containers of 4 minerals (minerals were stored in tennis ball containers and some samples repeated each other, but most randomly drawn containers would not contain any matching samples). The goal of this lab was to practice making observations of the various properties of common minerals: cleavage, luster,

hardness, streak and color. Often times, these are the same properties that make each particular mineral valuable; i.e. softness and luster of gold, hardness of diamonds and quartz, etc.

Each group of students collaboratively worked together to find the identification of their unique group of minerals. Students ranked this lab higher than the Mineral Identification Lab #1 with an average score of 4.4 out of 6. The students themselves did well with an average score of 94%. I believe it was ranked higher because each group had a unique collection of minerals, so they had to figure it out as a group without the possibility of help from other students in separate groups.

What followed was a review of the unit and the exam (Appendix A-III). The review was a basic review sheet that included information from the lectures, demonstrations, assignments and laboratory investigations. The exam was a little different from some of the exams I have given in the past. There was a laboratory investigation portion where the students moved to the lab section of the classroom. Each student was given four random minerals. The goal of the lab portion of the test was not for them to memorize the names of the minerals, but to accurately identify the key properties of that mineral.

C. Igneous Rocks

I began each segment of our study of rocks with a quick pre-assessment (Appendix A). I also started the unit with a pre-assessment about the rock cycle (Appendix A-IV). I debated whether or not to discuss the rock cycle at this point since the students have not had much background on this topic. I concluded that the students needed to have a fundamental understanding of the rock cycle before learning the details of each rock type. What was the rock before it was granite? What was the rock before it was sandstone? How about Gneiss? I wanted the students to start thinking about where the rock came from and where could it go under certain conditions well before they started dissecting the formation of each particular rock type. The rock cycle ended up as my main theme of the unit. I was always asking the students, in labs, discussions, homework assignments, exams and even on a one-to-one basis how to use the rock cycle to explain how the rock came to be.

1. Computer Lab: Rocks

To enhance their understanding of rocks and the rock cycle, one of their first assignments was a computer lab (Appendix B-VI) using a computer program called GEODe from the Tarbuck and Lutgens Geology textbook (Lutgens &

Tarbuck, 2000). It provides a nice introduction to the rock cycle and to the formation of rocks.

The computer lab was a nice transition for the students to the rock cycle. The program provided plenty of visuals and animations to assist the students in their learning of the rock cycle. One particular section, follows the transition of a piece of granite being weathered and sorted into sand, the sand into sandstone and finally ending up with a piece of quartzite. Overall the students gave it a positive review of 5.3 out 6 and their average score was a 96%. The high average score can be attributed to the fact that the activity was designed to guide them through the computer program with no critical thinking questions.

2. Igneous Rock Lab

I followed the computer lab with a set of notes on Igneous Rocks. As with the mineral notes, I designated a large percentage of the notes to Michigan's volcanic rock history. It is pretty exciting for some of the students to learn that Michigan at one time was volcanic.

The Igneous Rock Lab (Appendix B-VII), was designed to help the students learn the properties of igneous rocks. I improved upon a preexisting lab by developing some critical thinking questions geared towards the rock cycle in an

effort to really make the students think about why igneous rocks have the characteristics they have. The essence of the lab was to distinguish the characteristics of the various igneous rocks: mineral makeup and texture.

I urged the students to think about scenarios where rocks like the specimens provided could form. For example, the rocks pumice and scoria have a vesicular texture, which means that there are bubbles of trapped volcanic gases within the rock. I asked the students a scenario where this kind of rock could form. My expectations was that the students would ultimately discuss the possibly formation of rock as lava is ejected from a volcanic eruption.

In addition to the rocks they already had identified, I also added two more rocks, diorite and granitic pegmatite. Diorite is very similar to a rock they previously identified, rhyolite, being that it is both felsic and aphinitic (extrusive with small crystals). I asked the students to explain how diorite received these characteristics. I expected that they would be able to distinguish that it was felsic, because of the light color and that it was volcanic, or extrusive, because it had small crystals only visible through a magnifying glass.

I also gave them a piece of pegmatite. Pegmatite, as described in the science background, is not truly an

intrusive, plutonic igneous rock, however it does have very large crystals. I allowed the students to observe the piece of granitic pegmatite and a regular piece of granite and asked them to make some educated conclusions about their formation. I expected them to conclude that pegmatite must be an intrusive felsic rock because of the large crystals and silicate minerals.

In response to these two questions, my students tended to explain what the texture and color of the rocks were instead of how they achieved these characteristics.

I did not have enough time in class to implement the Igneous Rock lab as I had intended. As a result the students felt rushed and ended having to do answer a lot of the questions at home. This may have worked out for the best. The next class period we took out the rocks and placed them on their desks and reviewed the lab right then and there. This worked out well because it allowed the students to directly see each aspect of the questions they had answered at home using the rocks.

The students ranked this assignment 4.6 out of 6. The average score was high, 96%, since we reviewed together in class as a result of running out of time.

3. Igneous Fudge and Pumice Candy

To demonstrate the basic nature of crystallization during igneous rock formation, I offered each of my students an extra credit opportunity. The students were to make fudge at home and bring it in to class. However, they were not to make just any fudge. They were to follow the recipe I had provided them (Appendix B-VIII). In an effort to grow varying sized sugar crystals, there were four different cooling processes they could follow. The students who volunteered to make the fudge were told explicitly how to COOL their fudge. Some students cooled their fudge in the freezer, representing fast cooling and small crystal size. Some cooled them in the refrigerator, which should result in slightly larger crystals, but still on the small side. The third group would cool their fudge on the countertop overnight. The final group would cool their fudge the most slowly of all four groups, by quickly placing it in the oven at 200⁰F for one hour, then on the countertop over night. This should result in the largest, most coarse texture of all.

As a demonstration on the unusual formation of the igneous rock Pumice, I made a type of candy, known as Sea Foam candy, that I lovingly call Pumice Candy (Appendix B-IX). The idea is to mimic the formation of Pumice. Pumice

is unique because the lava cools so quickly that it traps dissolved gases as they try to escape from the lava. The result is a rock that has such a low density that it can float on water. Pumice candy does the same thing. When you boil some Karo Syrup and sugar mixture in a pot, and add a small amount of Baking Soda; carbon dioxide is immediately released. If you dump the mixture on tin foil sheet, the candy will harden and trap gas bubbles within resembling the rock pumice.

Fudge Day was far and away the favorite activity of the students in the entire unit earning 5.9 out of 6. Not only were the students able to eat fudge and pumice candy, but we were able to sit around the lab table and discuss what we were eating. The students watched as I made pumice candy and were able to see how the bubbles were trapped within the hard candy as it cools (vesicular texture). The fudge was not the best tasting fudge, but it did show crystal formation under different temperature regimes. The students who allowed their fudge to cool slowly, in most cases, had large sugar crystals. The students who allowed the fudge to cool quickly had small crystals leaving a smoother texture.

D. Sedimentary Rocks

After the Sedimentary Rock pre-assessment (Appendix A-VI), I briefly reviewed sedimentary rocks, since they have some knowledge of them from the rock cycle material discussed earlier, and provided a little depth about Michigan's sedimentary rocks.

1. Making a Sedimentary Rock

The formation of a rock from the cementation of previously weathered rocks can be very confusing. In years past, my students struggled with conceptualizing the lithification of sediment into sedimentary rock. With the help of Merle Heidemann and Duncan Sibley (Michigan State University), I developed a lab where the students can see the process themselves called Making a Sedimentary Rock (Appendix B-X).

Students used sand as their source of sediment and a supersaturated solution of Epsom Salt and distilled water. By completely soaking the sediment with the supersaturated Epsom salt and water mixture, they were able to see how water and dissolved minerals can move through sediment. We were also able to discuss how the minerals dissolved in water in nature can play a very similar role in sedimentary rock formation. Once the students flooded the sediment with water, they place the mixture in an incubator over night at

about 30°C to allow the water to evaporate. Once the water evaporates, the Epsom salt crystallizes and cements the sand together. Thus, the students have modeled the formation of sandstone.

To follow-up, I asked the students to discuss the formation of sandstone starting from a piece of granite. This is the first multiple step rock cycle question posed to the students. Some of the students were able to decipher that the sand has to come from somewhere first. Working in groups allowed for these students to help along some of other students. For those groups who needed some prodding along, I provided additional help.

The students performed this lab with only minimal exposure to the formation of sedimentary rocks through our rock cycle discussions and the computer lab. The original lab instructions called for heating the mixture of super-saturated solution of water and Epsom salt with the sand sediment on a hot plate. The length of the class period was not long enough for it to dry, so instead we placed the mixture in an incubator over night. The results were marvelous. Most of the students were able to remove their rock from the paper cups and take them home without much of a problem. Some students did not super saturate the

solution; the result was insufficient cementation. Overall, the lab was a huge success with a ranking of 5.2 out of 6.

On this lab, there was another rock cycle style question. It asked:

Use the rock cycle to describe the formation of quartz sandstone.

Some of the students were able to decipher that the sand has to come from somewhere. Since we had just talked about igneous rocks, most students were aware that granite is the most common rock on the Earth's surface and the parent material of most sediment. Many students prior to this class were aware of sand being comprised mostly of quartz. Quartz is common to granite and many were able to deduce that granite must have weathered and released the quartz crystals as sand. The sand then needed to be deposited and lithified. Overall, for their first attempt at the rock cycle on their own, I was impressed with their deductive ability. I had to prod along some students, but most students were able to answer this question at an adequate level and some at a superb level.

From their experience with the lab, they were able to determine that this sand must somehow be glued together. I followed this question with:

Explain how you could weather your sandstone so that you can get the sand back?

I had not discussed the process of weathering in detail at this point. However, with their experience with this lab and their experience with table salt and water, most of them were able to reason that water could dissolve the salt and release the sediment.

Students overall performed well receiving an average score of 82%. The score being slightly lower due to the intensity of the critical thinking questions. Most students responded to the first critical thinking question without using the correct terms. Many used it and this without explaining what they were referring to. This was one of the few labs that ranked high, but had a lower average score.

2. Making a Precipitate

Precipitation, in the chemical sense as opposed to the meteorological, is a very difficult concept for students to visualize. Consequently, I adapted a common chemistry exercise which I called Making a Precipitate (Appendix B-XI). Students mix CaCl_2 (calcium chloride) solution with Na_2CO_3 (Disodium Carbonate) solution to produce a CaCO_3 (calcium carbonate, or the mineral calcite) precipitate. Students are able to discover what an aqueous solution is and that in nature a solid can form from liquids. This process occurs in nature as well to produce the mineral calcite, or the sedimentary rock limestone.

I took the rock cycle questions to the next level and asked the students the following:

Some calcium (Ca) is weathered down from plagioclase feldspar (called anorthite) in the igneous rock granite. The released calcium reacts with carbonic acid (H_2CO_3) in water to form $CaCO_3$ (calcium carbonate). Using the rock cycle, explain the formation of limestone from the igneous rock granite. Use as many steps as necessary but you should have at least 3.

There could be many steps beyond three, and if the students read the question carefully, they would notice that I provided numerous hints to at least two of the possible three required steps. I said that calcium is weathered (step one) from feldspar in granite. I also provided them with the information that the calcium will react with carbonic acid to precipitate calcite (a possible step two). Although they could have used this as a step, I did not grade this particular step as necessary. I was more concerned that the students understood that following precipitation the calcite must be deposited and then lithified into stone. In short, I was expecting that the students would recognize, in very basic terms, that the weathering of granite as the essential first step, the precipitation of calcite as the next step and finally the lithification of the deposited calcite as the third and final step. Most students responded to this question with the deposition and cementation of the calcite mineral as the third and final step.

The students ranked this particular lab fairly low with a score of 3.9 out of 6 even though they had a high average score of 87%. Mostly this was attributed to the difficulty of explaining how a precipitate can form in nature. I think the students were accurate in that I did not do a decent enough job of relating the job to what actually happens. In the future I will most likely skip the lab portion and use it as a demonstration in front of the entire class. This way I can discuss the steps that occur in nature for the event to occur while the students are watching the precipitation process take place.

3. Lab: Sedimentary Rocks

The goals of this investigation (Appendix B-XII) were 1). Understand the differences between clastic sedimentary rocks and nonclastic. 2). Understand the conditions necessary for the formation of each.

Each lab group begins the laboratory investigation by carefully identifying each rock type as either clastic or nonclastic. There are three clastic sedimentary rocks in the container: shale, sandstone and conglomerate. The three nonclastic sedimentary rocks are the organic sedimentary rocks, coquina and bituminous coal, and the chemical sedimentary rock limestone.

Some of the critical thinking questions the groups answered dealt with the circumstances of formation of each rock. Each group also used a sedimentation tube to study the energy required to move various sized sediments in water. Within the tube, the slightest movement will cause silt and clay to immediately move around the tube, while sand and gravel need a bit more motion for them to be thrust around the tube. I asked the students to use the sedimentation tube as an example of how each of the clastic sedimentary rocks formed. What must the environment of each rock have been like? For example, since shale is made of clay and clay is so small, it is easy to keep it suspended within water. In order for it to settle and eventually become solidified as rock, the water needs to remain virtually still. Since rocks like sandstone or conglomerate need a tremendous amount of energy within the water to move the sediment, the environment they form in will be entirely different.

To determine how well they understood this process I asked the students the following question:

Using the clastic rocks above, choose one and describe how it may have formed and what it tells us about the surface of the Earth at that location and time.

Most students chose either shale or conglomerate being that they were the two extremes. They were adequately able to

describe possible scenarios where these could form. In response to the question, students would explain the formation of the sediment in very broad terms. For example, "sand originated from granite."

I wanted to use the rock cycle to explain the formation of a chemical sedimentary rock as well. I asked them the following:

Halite is an example of a nonclastic chemical sedimentary rock. Use the rock cycle to describe a scenario of how it could form.

The students were aware that Halite is a salt; they were able to deduce that water must have evaporated and left the salt behind. From there, some students had difficulty. Some were not able to recognize that the leftover salt particles were just another type of sediment. In the end, all groups came to the conclusion that the salt sediment was compacted and cemented together just like any other sediment to form a sedimentary rock, in this case halite.

The lab received 4.1 out of 6 and the average percentage was 83%. Overall, I thought the additions I made to the lab experience helped the students to understand the formation of clastic and nonclastic sedimentary rocks. I will use this lab in the future.

E. Metamorphic Rocks

Following the metamorphic pre-assessment (Appendix A-VII), I began this portion of the unit with some metamorphic rocks in Michigan information. I mostly talked about the formation of the iron ore in the Upper Peninsula, but I also talked about the metamorphism of amygdloidal basalt and conglomerate through hydrothermal vents resulting in huge amounts of deposits of copper and some small amounts gold and silver.

1. Metamorphic Cookie

I used the rock cycle to explain metamorphism. The idea was for the students to think about what happens to a rock's crystal structure when it is put under extreme heat and pressure, but NOT melted. This is tricky for students to understand. How can rocks be heated but not melted? I used the baking of a cookie as a model: cookie dough is not melting but changing at an atomic level. A chemical change has occurred, and the cookie cannot be changed back by physical means; i.e. melting or cooling etc. After this analogy, each student was given a soft chocolate chip cookie and as I was discussing metamorphic rocks and metamorphic change, each student sat on their cookie (between two pieces of paper towel). As the discussion went on, the cookies were under a great bit of stress and some

heat as well (some more than others). The point of this demonstration was for them to see how various minerals can become foliated in a metamorphic rock. The stress the rock/cookies are under influence further crystal formation to stimulate growth in the opposing direction of the stress. You can see fairly clear foliation between the chocolate chips because the chocolate chips were allowed to expand outward due to the pressure exerted onto them.

The chocolate chip cookie demonstration was successful and was given a rank of 5.8 out of 6. The students liked eating the cookie, while I liked how well it shows the foliation of some metamorphic rocks. What I made sure the students understood was that they did not melt the cookies, but allowed them to re-crystallize. I also asked them, if I had changed the cookie from chocolate chip to a sugar cookie (containing no chocolate and is more of a homogeneous mixture) would we have observed any foliation? We were able to discuss that similar to metamorphic rocks, if the object contains more than one substance, like a chocolate chip cookie or a rock with more than one mineral, then you will see evidence of this by foliation. On the other hand, if there is only one mineral in the rock or a homogeneous mixture within the cookie, then you will not see any foliation.

2. Metamorphic Rocks Lab

For the Metamorphic Rocks Lab (Appendix B-XIII), students determined whether six metamorphic rocks were either foliated or nonfoliated. To identify the rocks, the students needed to recognize that the foliated rocks would have some kind of layering or bands of color representing the various minerals found within the rock. Nonfoliated rocks have no banding or layers and generally only one color due to the presence of a single mineral.

The groups were provided with parent rocks (preexisting rock) and daughter rocks (new metamorphic rock) and asked to describe some of the evidence that suggests they are related and what processes occurred to form the daughter rock. For the metamorphic rock gneiss, a sample of the igneous rock granite was provided. The two samples have much in common, such as, similar colors, similar crystals, and similar hardness. The shared color could indicate that they have the same minerals. The similar hardness and crystals could provide more evidence of this.

I used the same format with the sedimentary rock shale and the metamorphic rock slate. At this point in our rock unit, the goal was that the students would have reached a level of understanding of the rock cycle that they could

work their way through the cycle from multiple angles. I asked the students to start with the igneous rock granite and explain the formation of the sedimentary rock shale and then the formation of the metamorphic rock slate. This is very difficult and the students must have a strong understanding of the rock cycle. The expectation was a response starting with the weathering and erosion of granite to clay. They then needed to take it another step and explain that the weathered material must be deposited, compacted and cemented together to form the sedimentary rock shale. Shale, then, would need to be put under heat and pressure to change into its metamorphic counterpart, slate. Many students did not receive full credit for this question because they tended to stop at the formation of shale.

Another thought provoking question in this lab was to compare the sedimentary rock limestone with the metamorphic rock marble. Both are made of the mineral calcite and thus react positively with a dilute solution of hydrochloric acid. The initial question was simple enough.

What test could you perform to provide evidence that marble is related to limestone? Using this evidence, explain why marble has large crystals and limestone has nearly no visible crystals at all.

Both rocks would react positively to an acid test. The students would have to explain that during metamorphosis,

the increase in temperature and pressure allows the crystals to re-crystallize and grow larger. In response to the second question, students tended to explain the crystals in marble by their exposure to more heat and pressure.

Having parent rocks and the corresponding daughter metamorphic rocks helped the students visualize the change that takes place during the process of metamorphosis, especially, between the igneous rock granite and the metamorphic rock gneiss. According to the lab evaluation and the performance of the students during the lab, the students were able to make the connections between the two of these rocks since their appearance to one another are so similar. In their explanation of the evidence for the relationship between these two rocks, many of the students referred back to the metamorphic cookie demonstration to explain the foliation of the mineral crystals in the metamorphic rock gneiss.

The lab received a score of 4.0 out of 6. The average percentage was an 84%. I believe the changes made to this benefited the students understanding of the material. As a result, I will use this lab again.

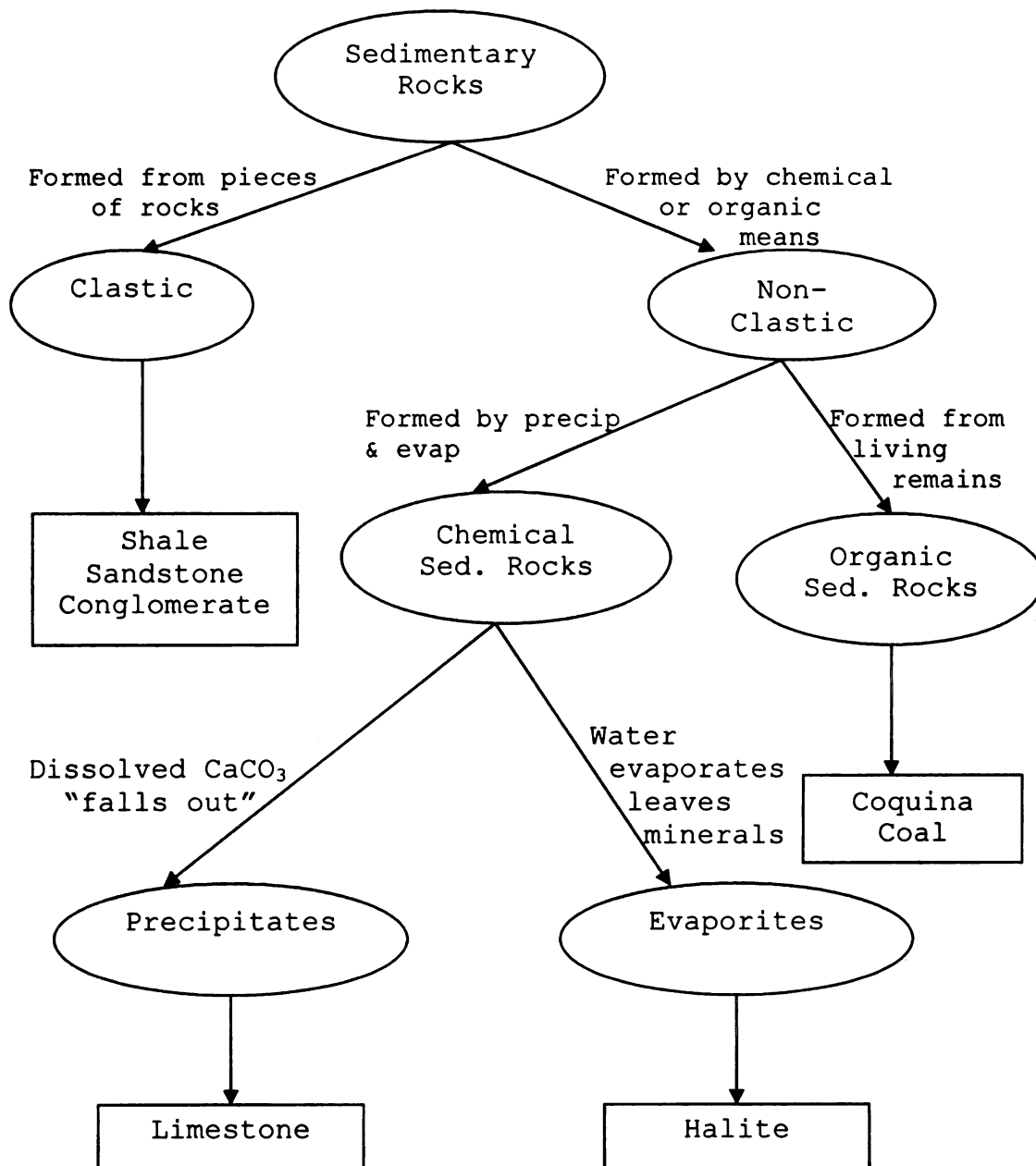
3. Rock'n Brainstorm

The final assignment was a computer lab called "Rock'n Brainstorm" (Appendix B-XIV). The students used a computer program called Inspiration that allows the students to develop concept maps. Although it is a wonderful program and it is easy to use, the same objective can be accomplished using Microsoft Word or even pencil and paper. The objective of this assignment was for the students to organize the data they have acquired in the rock unit.

The students individually developed a concept map for each type of rock. After successful completion of each rock type, I then asked the students to create an example of the rock cycle.

The following is an example of the expected outcome for the concept map for sedimentary rocks. Most students were able to create a map that allowed the concepts to flow in a natural method from one concept to other. According to the student surveys, they found that this activity helped them to organize their thoughts and ideas into a structure that they could use to more easily study for the test. Some even went to so far to say that they would use this method for future tests in this class and other subjects.

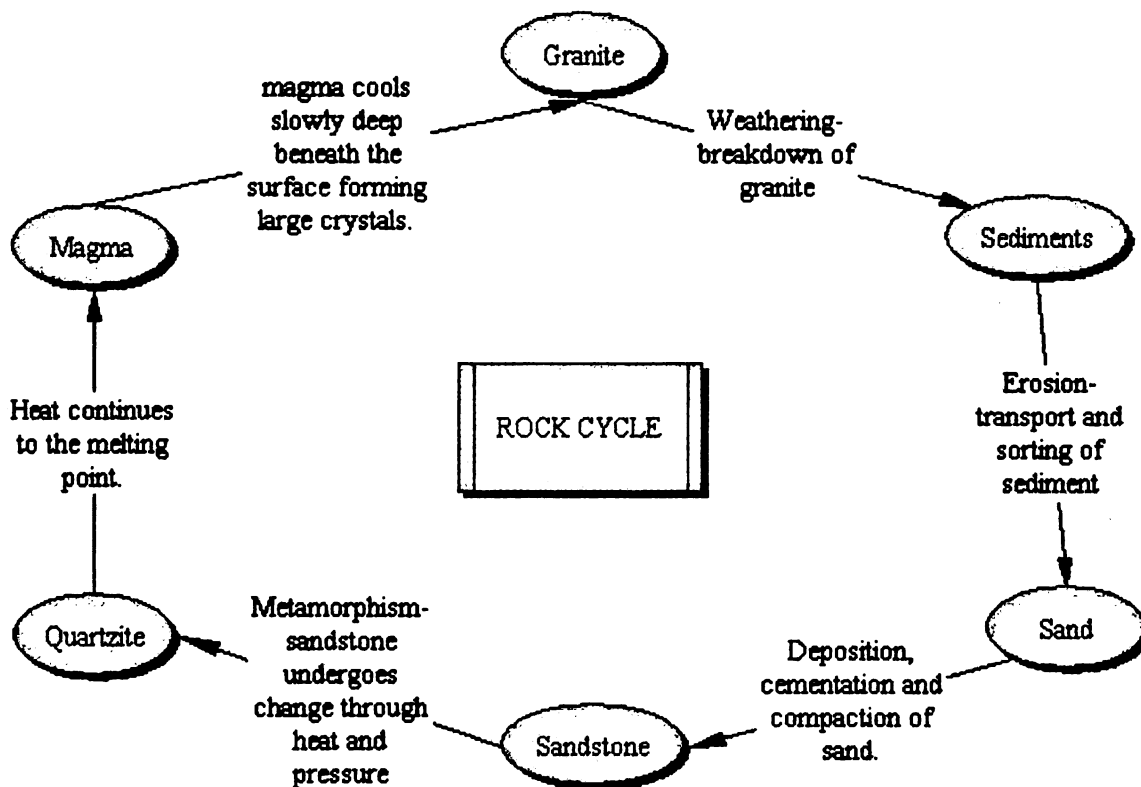
Figure 1: Example of the Sedimentary Rock Brainstorm



The students also were asked to create a rock cycle starting from granite, eventually forming quartzite, and then ending with granite again. The results were mixed. I asked for at least 6 steps, but it could have been done in less. Some students caught on that you could easily have

the cycle take any turn you would like on the cycle and fill in needed steps. Figure 2 is an example of what I was expecting to see from all of the students.

Figure 2: Example of the Rock Cycle Brainstorm



Overall the activity was successful in that it provided an opportunity for the students to re-think what they have learned and organize it in a way that could help them understand the material. The students enjoyed the activity and ranked it with 5.1 out of 6 and earned an average score of 86%. I will use this lab not only in my rock and mineral unit but in other units as well.

RESULTS AND CONCLUSIONS

I. Analysis of Pre-tests and Post-tests

To determine if the new laboratory investigations and the modified lab experiments did indeed enable students to increase their scores between the pre- and post-test, I used the Student's t test. In all five of the pre-tests and post-tests, the Student t test showed that there was a statistically significant difference between the pre- and post-test scores. This suggests that the students were able to significantly increase their scores.

The following information is necessary to perform the Student t test. The pre- and post-test means are groups 1 and 2 respectively. This test was performed on each of the five exams.

$$t = \frac{X_2 - X_1}{S_{DX}}$$

where

X_1 is the pre-test mean for a given pre-test

X_2 is the post-test mean for a given post-test

S_{DX} is the standard difference of the mean

Degrees of freedom = 79

Test	t value	significant at the .001 level
Chemistry & Minerals	17.4	Yes
Igneous Rocks	14.7	Yes
Sedimentary Rocks	16.5	Yes
Metamorphic Rocks	10.5	Yes
Rock Cycle	15.5	Yes

All five tests had a t value over 10. This suggests that the implementation of this unit played a significant role in the difference in the mean pre- and post-test scores at the 0.001 level.

II. Conclusion

I strongly believe that a well rounded cooperative learning based science curriculum with truly thought provoking critical thinking questions embedded within the entire curriculum is the most effective way for me teach the curriculum. In addition, the inclusion of the rock cycle throughout laboratory investigations, homework assignments, lectures and exams genuinely helped the students understanding of the process, as the data from the pre and post-assessment supports. The students understand not just the identification of the rocks and minerals but the formation and the environment of formation for the different types of rocks and minerals.

For the first time since teaching this unit on Rocks and Minerals, I feel that I have accomplished my goal of keeping the students interested in a topic that can be very difficult for the students to understand. It is my belief that the structure of cooperative learning and the demands of critical thinking fosters an environment in the

classroom that encourages the students to excel. During the implementation of this unit the students were pushed to continue analyzing and thinking about the various problems. In most cases they met my expectations, without quitting or complaining at the difficulty of the lesson. It is because of the success this unit has had and because of the interest level the students have sustained throughout the unit that I will incorporate critical thinking analysis and cooperative learning lessons not just in my future rock and mineral units, but throughout my entire curriculum.

In conclusion, I believe that I have demonstrated that using a cooperative learning and critical thinking laboratory investigations approach to teach concepts in a ninth grade geophysical science course will lead to student learning and success.

APPENDICES

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APPENDIX A

Evaluation Tools

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A-I Lab Evaluation

Activity Name: _____

1. Rank the lab on how well it helped you learn the topic: 1 being very helpful/I learned a lot or 6 being very confusing/I didn't learn a thing.

2. What was the main objective of this lab?

3. Think of an example where the information from the activity can be applied.

4. Tell me what you liked and disliked about the lab.

A-II Pre-Assessment: Minerals

(Answers written below question in italics)

Multiple Choice

1. What state must a substance be in for it to be considered as a mineral?

- a liquid b Gaseous c solid d organic

Answer: solid

2. What elements are the most abundant in the Earth's crust?

- a aluminum & potassium c oxides & carbonates
b halite & coal d oxygen & silicon

Answer: oxygen & silicon

3. Silver, gold, and copper have shiny surfaces. What type of mineral property is this?

- a luster b hardness c cleavage d streak

Answer: luster

4. Unlike sugar, why is halite, salt, considered a mineral?

- a it's organic c it's a crystal
b it's inorganic d it's not naturally occurring

Answer: it's inorganic

5. What is the most common mineral family?

- a carbonates b non- c silicates d non-
 carbonates silicates

Answer: silicates

6. What is the Moh's scale used to measure?

- a cleavage b luster c color d hardness

Answer: hardness

7. The mineral mica can break apart in sheets. What is this property called?

- a cleavage b luster c color d hardness

Answer: cleavage

8. What type of change occurs when you burn a piece of paper?

- a physical b chemical c biological d geological

Answer: chemical

A-III Post Assessment: Minerals Test

Matching

Use the following choices to answer the questions below.

A Physical Change

B Chemical Change

1. A car crash (fender bender)
2. Steel wool demo (gaining mass)
3. Glass breaking
4. Iodine demo (sublimation)
5. A car rusting
6. Spilling bleach on your jeans
7. Drying your hair

Use the following choices to answer the questions below.

A Silicate

D oxide

B Carbonate

E halide

C Sulfide

8. SiO_2

11. NaCl

9. CaCO_3

12. Fe_3O_4

10. ZnS

Use the following choices to answer the questions below.

A cleavage

D luster

B fracture

E streak

C hardness

13. Measure of how easily a mineral can be scratched
14. Property of splitting along one or more flat planes evenly and easily
15. The way a mineral reflects light from its surface
16. Color of a mineral when it is broken up and powdered
17. Property of breaking with rough or jagged edges

Use the following choices to answer the questions below.

A crystal

C mineral

B silicate

D ore

18. Solid in which the atoms are arranged in repeating patterns
19. Mineral that contains silicon and oxygen
20. Naturally occurring, inorganic solid with specific chemical composition and crystalline structure
21. Mineral that contains a useful substance that can be mined for profit

A-III Continued

Multiple Choice

Identify the letter of the choice that best completes the statement or answers the question.

22. Silver, gold, and copper have shiny surfaces. What type of mineral property is this?

- A luster B hardness C cleavage D streak

23. Minerals always exist in a(n) _____ form.

- A solid B liquid C gaseous D organic

24. What elements are the most abundant in the Earth's crust?

- A halite and coal C oxygen and silicon
B aluminum and potassium D oxides and carbonates

25. What type of change occurs when you burn a piece of paper?

- A physical chemical C biological D geological

26. Moh's scale is used to compare the _____ of minerals.

- A cleavage B luster C color D hardness

27. The mineral muscovite mica can easily break apart in to flat sheets. What mineral property is this an example of?

- A color B hardness C cleavage D luster

28. Unlike sugar, why is halite (table salt), considered a mineral?

- A It's organic C it's a crystal
B It's inorganic D not naturally occurring

29. What is the most common mineral family?

- A carbonates B non- C silicates D non-
 carbonates silicates

Short Answer

30. Geologists use multiple identification tests to accurately identify a mineral. Explain why it is necessary to do this and provide an example.

31. Explain why table salt (NaCl) is not explosive or poisonous, when we know Na is explosive and Cl is poisonous.

A-III continued

32. Which is a more reliable method of identifying a mineral - streak or color? Explain why.

33. If you took random samples of minerals from several locations, which type of mineral would you likely have more of - oxides, silicates, or carbonates? Be specific in your explanation as to why this would occur.

34. List 4 of the 5 parts of the definition of a mineral.

A-III continued

Lab Portion

Mineral Identification: **Form:** _____

1. Do the tests for each mineral FIRST and WRITE in your findings in the squares.
2. Compare your findings with the KEY below the squares.
DO NOT CHANGE your original answers. For example, pretend you guess the name of the mineral incorrectly and then you decided to change all of your answers to match the name, you could have lost all of your points instead of just one. DON'T CHANGE ANSWERS TO MATCH THE NAME.
3. Write the name of the mineral that BEST matches your findings.

Mineral (name)	Color	Streak	Luster	Hardness
A				
B				
C				
D				

Choose the mineral that best fits your tests above.

Magnetite	Black	Black	Metallic	5-7	
Graphite	Black	Black	Metallic	1-3	
Pyroxene	Black	None/Green	Black	Glassy	5-6
Calcite	Varies	None	Glassy	3-4	
Chlorite	Green	Green/black	Glass	1-3	
Orthoclase	Varies	None	Glassy	5-7	
Talc	White	White	Glassy	1-2	

A-IV Pre-Assessment: Rock Cycle

Use the rocks in the containers to help you draw a rock cycle. The goal of this rock cycle is to begin with a sedimentary rock and work through the entire rock cycle, so that the end result is another sedimentary rock. You can choose from the terms below, but you do not NEED to use all the terms. You must use ALL 3 rock types and the sedimentary rock you start with MUST be different from the one you end with.

You DON'T need to use all of these

- Granite (igneous rock #1)
- Rhyolite (igneous rock #2)
- Sandstone (sedimentary rock #13)
- Shale (sedimentary rock #11)
- Conglomerate (sedimentary rock #15)
- Quartzite (metamorphic rock #18)
- Gneiss (metamorphic rock #17)

You MUST use all of these

- Heat and Pressure
- Erosion/sorting
- Cementation and compression
- Molten rock
- Cooling and crystallizing
- Weathering
- Sediments

Use the space below to draw your rock cycle

A-V Pre-Assessment: Igneous Rocks

1. Intrusive igneous rocks form ____.

- A fine-grained rocks c on Earth's surface
B when molten rocks cool quickly d coarse-grained rocks

Answer: coarse-grained rocks

2. Igneous rocks that cool quickly on Earth's surface are called?

- A extrusive b Intrusive c metamorphic d always magnetic

Answer: extrusive

3. The size and arrangement of the crystals in an igneous rock is called?

- A hardness b Density c texture d luster

Answer: texture

4. Magma is

- A molten material which cools and solidifies to form an igneous rock.
B molten material which liquefies to form lava.
C an igneous rock which melts and becomes lava.
D a lava fountain that cools and solidifies to form molten rock.

Answer: an igneous rock which melts and becomes lava.

5. In an igneous rock, crystal size is interpreted to imply which of the following?

- A How the magma felt during cooling
B Time allowed for cooling of the magma/lava
C temperature of the magma
D chemistry of the magma

Answer: Time allowed for cooling of the magma/lava

6. Light colored, silica rich igneous rock is what type of igneous rock?

- A felsic b mafic c ultramafic d ultrafelsic

Answer: felsic

7. The most common mafic rock is?

- A granite b basalt c pumice d obsidian

Answer: basalt

Multiple Choice

1. What is a clastic sedimentary rock?

- A A rock that contains groundwater
B A rock formed by cementation of rock fragments
C A rock formed from evaporation
D transformed into limestone from heat and pressure

2. A positive acid test indicates that the sedimentary rock limestone contains what mineral?

- a calcite b feldspar c halite d quartz

3. Organic sedimentary rocks are made of?

- | | |
|-----------------------------------|--------------------------------------|
| a plant and animal remains | c rocks changed by heat and pressure |
| magma that cools and crystallizes | d small rocks cemented together |

4. Rock salt, halite, is an example of what type of sedimentary rock?

- a organic b clastic c evaporite d precipitate

5. What type of environment does the sediment clay need in order to settle and deposit?

- a fast moving shallow water c medium speed shallow water
b fast moving deep water d virtually still deep water

6. Sedimentary rocks form in layers with the oldest layer of rock on the .

- a top b bottom c middle d surface

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A-VII Pre-Assessment: Metamorphic Rocks

Multiple Choice

Identify the letter of the choice that best completes the statement or answers the question.

1. The metamorphism of limestone results in the formation of ____.
A quartzite B marble C gneiss D silver
2. Metamorphism is best defined as the
A precipitation of minerals dissolved in water
B compaction and cementation of rock fragments
C molten rock cooling and crystallizing
D changing of rock from heat pressure
3. How can you tell if a rock is foliated?
A it is volcanic B it has layers C it is salty D crystal size
4. What results when a rock comes in contact with extremely hot, molten rock?
A precipitation C contact metamorphism
B regional metamorphism D hydrothermal metamorphism
5. Which of the following is NOT an agent of metamorphism
A heat B pressure C chemicals D cementation
6. Regional metamorphism refers to metamorphism
A that affects broad regions of the crust
B caused by intrusion of cold magma into hot rocks
C caused by the intrusion of hot magma into cooler rocks
D that is usually accompanied by melting
7. Pressure required for metamorphism can be generated by
A pressure from weight of overlying rock
B heat from magma in contact with surrounding rock
C cementation and lithification
D hydrothermal solutions.

A-VIII Post-Assessment: Rock-N-Test

Multiple Choice

Identify the letter of the choice that best completes the statement or answers the question. Carefully place the answer on your scantron.

1. Metamorphism is best defined as the
A precipitation of minerals dissolved in water
B compaction and cementation of rock fragments
C changing of rock from heat and pressure
D molten rock cooling and crystallizing
2. Regional metamorphism refers to a metamorphic change
_____ that is usually accompanied by melting
A that is usually accompanied by melting
B caused by intrusion of hot magma into cool rocks
C that affects large regions of the crust
D caused by intrusions of cold magma into hot rocks
3. Intrusive igneous rocks form _____.
A from rapid cooling of lava C coarse-grained rocks
B on Earth's surface D fine-grained rocks
4. Organic sedimentary rocks are made of?
A magma that cools and crystallizes C small rocks cemented together
B existing rock changed by heat & pressure D plant and animal remains
5. What results when rocks touch extremely hot, molten rock?
A precipitation C hydrothermal metamorphism
B contact metamorphism D regional
6. Igneous rocks that cool slowly beneath Earth's crust are _____.
A extrusive B sedimentary C intrusive D magnetic
7. A positive acid test indicates that the rock contains what mineral?
A calcite B halite C feldspar D quartz
8. How can you tell if a rock is foliated?
A it has layers B it is volcanic C it is salty D it speaks to you

9. Light colored, silica rich igneous rocks are called?
A ultramafic B mafic C felsic D ultrafelsic
10. What type of environment does the sedimentary clay need in order to settle and deposit?
A fast moving shallow water C fast moving deep water
B slow moving deep water D medium speed shallow water
11. Magma is
A molten material which liquefies to form lava
B molten material which cools and solidifies to form an igneous rock
C a lava fountain that cools and solidifies to form molten rock
D an igneous rock which melts and becomes lava
12. Extrusive rocks, which cool more rapidly than intrusive rocks, are generally more _____.
A magnetic B finely grained C radioactive D coarsely grained
13. Igneous rocks that cool quickly on Earth's surface are _____.
A metamorphic B intrusive C extrusive D magnetic
14. The size and arrangement of the crystals in an igneous rock is called?
A hardness B density C luster D texture
15. Sedimentary rocks form in layers with the oldest layer of rock on the _____.
A middle B surface C top D bottom
16. A rock composed mostly of pebbles/gravel cemented together is called?
A limestone B conglomerate C pumice D shale
17. In an igneous rock, crystal size is interpreted to imply which of the following?
A time allowed for cooling of molten rock C how the magma felt during cooling
B chemistry of the magma D temperature of magma

A-VIII Continued

18. What is a clastic sedimentary rock composed of?
A groundwater B rock C shells D evaporites
fragments
19. The metamorphism of limestone results in the formation of _____.
A silver B marble C gneiss D quartzite

Matching

Match each item with the correct statement below.

- | | |
|--------------|------------------------|
| A clastic | C contact metamorphism |
| B rock cycle | D sediment |
20. Type of sediment made up of rock and mineral fragments produced by weathering
21. Pieces of solid material deposited on Earth's surface
22. Occurs when small areas of rock are changed by touching hot material
23. Continuous changing and remaking of rocks

Match each item with the correct statement below.

- | | |
|---------------|---------|
| A felsic | C lava |
| B porphyritic | D mafic |
24. Magma that flows out onto Earth's surface
25. Texture characterized by large, well-formed crystals surrounded by finer-grained crystals of the same mineral
26. Light-colored rock such as granite that has high silica content
27. Rock that is very high in iron and magnesium

Match each item with the correct statement below.

- | | |
|------------------|-----------------------|
| A Extrusive rock | D Porphyritic texture |
| B Intrusive rock | E Mafic rock |
- C Felsic rock
28. Light color with high silica content
29. Dark color with high iron/magnesium content
30. Large and small crystals in the same rock
31. Fine-grained, small or no crystals
32. Coarse grained/ large crystals

A-VIII Continued

Lab Portion:

There are 3 containers of rocks to use on the test make sure you use the correct container for the different parts of the test. **MAKE SURE THE CONTAINERS CONTAIN THE ROCKS LISTED ON THE CONTAINER!!!!** Let your teacher know if you cannot read the number of the rock.

Part 1: Igneous Rocks: Use the igneous rocks (record the number) for each of the following questions. The number of lines is the number of answers. *** Only use rocks 1-8. Set rocks A and B aside.

More than one rock

made from magma _____

made from lava _____

formed with gasses present in the lava _____

extrusive rocks _____

intrusive rocks _____

One rock answers

deep in the crust and the surface _____

an intrusive, felsic rock _____

an extrusive, mafic rock _____

cooled VERY quickly _____

porphyry (intrusive and extrusive) _____

The color and texture of an igneous rock can tell you everything you need to know about it. Choose any igneous rock, **BESIDES** granite or basalt, from above and describe where it formed in the crust, from what type of crust and **HOW YOU KNOW**

Part 2: Sedimentary Rocks

Rocks 11, 13, and 15 are clastic sedimentary rocks. What does "clastic" mean? _____

____ clastic rock that formed in the
highest energy environment

____ made from sand-sized sediments

____ made from clay

____ formed in the highest
energy environment

____ made from gravel

Nonclastic rocks are numbers 10, 12, and 14. Rocks 10 and 14 have positive acid tests. Rock #10 looks like a piece of granola bar.

____ this rock is made from shells that
have been pressed together

____ made from minerals that "fell out" or
precipitated from sea water

____ organic sedimentary rocks

____ made from plant material

____ rock salt is made the
same way as this rock

____ chemical sedimentary rock

Explain how do sedimentary rocks show earth history? Describe 2 out of the 3:

A-VIII Continued

Part 3: Metamorphic Rocks Rock numbers 16-21 with rocks 1,11,13,14

Rocks 14 and 16 have a positive acid test.

***For the answers below, choose from rocks 16-21

_____ are the foliated metamorphic rock(s)	_____ nonfoliated
_____ is the daughter rock of granite (#1)	_____ is the daughter rock of
_____ is the daughter rock of shale (#12)	limestone (#14)

Compare rock 16 and 17. Rock 17 has multiple colors, whereas rock 16 only has one (please disregard ink). Explain how this can occur.

Part 4: Rock Cycle

The goal of this rock cycle is to begin with a sedimentary rock and work through the entire rock cycle, so that the end result is another sedimentary rock. You can choose from the terms below, but you do not NEED to use all the terms. You must use ALL 3 rock types and the sedimentary rock you start with MUST be different from the one you end with.

You DON'T need to use all of these

- Granite (igneous rock #1)
- Rhyolite (igneous rock #2)
- Sandstone (sedimentary rock #13)
- Shale (sedimentary rock #11)
- Conglomerate (sedimentary rock #15)
- Quartzite (metamorphic rock #18)
- Gneiss (metamorphic rock #17)

You MUST use all of these

- Heat and Pressure
- Erosion/sorting
- Cementation and compression
- Molten rock
- Cooling and crystallizing
- Weathering
- Sediments

Use the space below to draw your rock cycle

APPENDIX B

Laboratory Investigations

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B-I Chemical & Physical Changes

Definitions:

Element- cannot be broken down into simpler substances.

Atom- the smallest amount of an element that has all the properties of the element.

Mixture- 2 or more substances physically combined. Can be broken down by a physical change.

Ex. Salt water, sugar dissolved in water, sand (mixture of different minerals)

Compound- 2 or more elements chemically combined. Can only be broken down by a chemical change.

Ex. Salt (NaCl), sugar (C₆H₁₂O₆), HCl (hydrochloric acid), H₂O

Demo 1: Combustion of Steel Wool

Problem #1: Will steel wool burn?

Hypothesis: Make a prediction

Steel is an ALLOY: An alloy is a combination of metals that can be separated by melting. What classification of matter (element, compound or mixture) would this be? Circle your choice:

Data Chart:

Before: Mass of steel wool and foil: _____

After: Mass of steel wool and foil: _____

Was this a chemical or physical change? _____

Provide 2 pieces of evidence:

1). _____ 2). _____

Demo 2: Phase Change of Iodine

On your own:

Describe what happened: _____

Was this a physical or chemical change? _____ What is your evidence? _____

What phase changes occur inside the test tube? _____

As you do the following experiments, carefully make and record your observations. Also, answer the questions before moving on to the next experiments.

Experiment #1: Hot Sauce and Penny

Materials:

- Paper towel
- Penny (preferably old and dirty looking)
- Hot sauce (preferably Taco Bell)

Procedure:

1. Place your penny on a piece of paper towel and cover the penny in hot sauce.

B-I continued

2. Rub the penny in the hot sauce for one minute. Even though it smells good, **DO NOT EAT THE PENNY!**

3. Clean the penny with the paper towel. Even though it smells good, **DO NOT EAT THE TOWEL!**

What happened to the penny? _____

Was this a chemical or physical change? _____ How do you know? _____

Experiment #2: The Candle

Materials:

- Candle
- Match
- Wet paper towel
- Aluminum Foil

Procedure:

1. Make sure your candle is secure in its tray.

2. Wet a paper towel and place it in the center of the lab table.

3. **MAKE SURE YOUR GOGGLES ARE ON!!!**

4. Light the match. **BE CAREFUL! NEVER** strike a match towards another person. Strike it towards the wet paper towel.

5. Light the candle and watch it burn for **ONE** minute.

a. What is happening to the wax near the flame? _____

Is this a chemical change, physical change or both? _____ How do you know? _____

b. What happens to the wax as it reaches the foil? _____

Is this a chemical change, physical change or both? _____ How do you know? _____

c. What is happening to the wick? _____

Is this a chemical change, physical change or both? _____ How do you know? _____

Experiment #3: The Mixture

In the beaker is a mixture of rocks and Kool-aid. Write a procedure describing how to separate the rocks, the kool-aid and the water. **INCLUDE** a description of any physical or chemical changes. Have your teacher check when complete.

B-II Crystallization of Thymol Melt

Materials:

- Thymol
- Beaker, water, and hot plate
- Microscope Slides
- Stereomicroscopes
- Goggles
- Droppers or pipettes

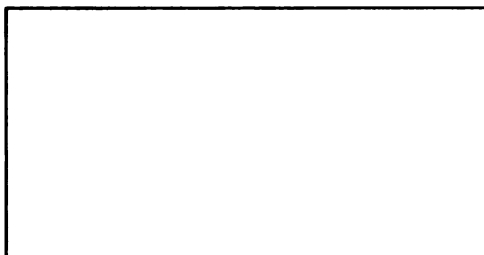
Procedure: Melt the Thymol

1. Boil 100 mL of water in the beaker.
2. When the water is boiling, place one scoop (just a few grains) of thymol on the watch glass (concave shaped glass) and lay the watch glass on top of the beaker.
3. The thymol should melt within a few minutes. Carefully remove the watch glass from the beaker.
4. Turn off hot plate and set aside. DO NOT TOUCH for the remainder of the class (it will be very hot).

Procedure: Crystallization of Thymol Melt with Seed Crystal

*** When you observe the crystallization of thymol, note how the crystals grow, the shape and size of the crystals, and how fast they grow.

1. Place ONE large drop of thymol melt onto a microscope slide.
2. Position the slide on the stage of the stereomicroscope, so that you can see the drop of thymol within the lens.
3. CAREFULLY place ONE grain of thymol near one edge of the microscope slide. Push it into the melted Thymol.
4. Observe the crystallization and sketch a characteristic crystal (what does a typical crystal look like).



Questions:

1. Observe a single crystal. Explain what you see. _____

2. Using what you have learned about crystal formation, describe why all of the individual crystals have the same shape. _____

B-II continued

Make a prediction about crystal size and shape after leaving it alone for 24 hours. _____

Clean up:

- **Rinse and dry the watch glass and return to the lab table. If you want to keep the microscope slide, you can. Otherwise, place in the glass disposal.**

B-III Mineral Identification Tests

Materials:

- | | |
|---|-------------------------|
| 1. Tennis ball container
with 11 mineral samples | 3. Glass plate |
| 2. Streak plates (square,
white/black porcelain) | 4. Iron bolt/Iron plate |
| | 5. Pennies |

Luster:

* The way a mineral shines in reflected light. If the mineral reflects light like a metal, then it has a **Metallic** luster. All other types of luster are referred to as **Nonmetallic**. However, there are categories of nonmetallic luster. **Glassy** (vitreous) and **dull** (earthy). Dull luster does not have a shine, so you should not see a "polished" sheen to it.

Divide the minerals into the following categories and place their number in the space provided:

*** HINT: You may have to look at the mineral at angle and up close to see the reflection.

Metallic: _____
Vitreous (glassy): _____
Dull: _____

Streak:

* The color of a mineral is an unreliable identification test, however, the color of a mineral in its powdered form (streak) is a much more consistent indication of its identity. The streak test is performed by scratching a mineral on a streak plate (unglazed porcelain plate) leaving behind a powder. The powder of the mineral can sometimes have a completely different color than the mineral itself! A mineral can leave a white/colorless streak often times being very difficult to see. Rub your finger along the plate to collect any powder.

Perform the streak test on the 11 minerals and record the color below in the space provided. The number of the mineral should match the number below.*** CAUTION: There is ONE mineral that is as hard as the streak plate!

#1 _____	#4 _____	#7 _____	#10 _____
#2 _____	#5 _____	#8 _____	#11 _____
#3 _____	#6 _____	#9 _____	

Hardness:

* Measures the strength of bonds that holds the mineral together. In other words, hardness measures the resistance of a mineral to scratching. See **Mohs Scale:**

Description of Hardness Test:

The Mohs scale is ranked from 1 to 10 with 1 being the softest and 10 being the hardest. THE MINERALS YOU ARE USING ARE NOT NECESSARILY THE SAME AS REFERENCED IN THE Mohs scale! Use the objects listed to test for hardness. For example, if your fingernail can scratch the mineral, then your fingernail is harder than the mineral, THEREFOR the mineral would have a hardness of a 1 or 2. SO, in this example, you do not NEED to test any further.

Determine the hardness of the minerals.

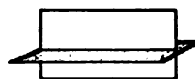
#1 _____	#5 _____	#9 _____
#2 _____	#6 _____	#10 _____
#3 _____	#7 _____	#11 _____
#4 _____	#8 _____	

Cleavage vs. Fracture:

* **Cleavage** is the tendency of a mineral to break along planes of weak atomic bonds. Basically, when the mineral is broken, it will break along flat planes creating relatively smooth surfaces. For example, the mineral Halite (commonly known as table salt) will break into cubes. It has 3 directions of cleavage, up/down, side to side, and front to back. Some minerals will only have cleavage in 1 direction, or even in 2 directions. The "other" directions would be considered fractured.



Sheet



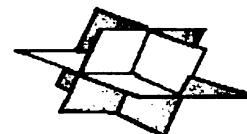
Blocky



Prismatic



Cubic



Rhombohedral

B-III continued

* **Fracture** does not break along a smooth flat surface. Most minerals fracture in irregular patterns (however, most of your samples will not).

CAUTION: Soft minerals will appear to have no cleavage if it has been handled frequently. Some harder minerals will fracture under enough stress even if it should cleave. Determine whether the mineral has cleavage or if it is fractured. If it does, determine how many directions (1,2, or 3).

1. _____

2. _____

3. _____

4. _____

5. _____

6. _____

7. _____

8. _____

9. _____

10. _____

11. _____

B-IV Mineral ID Lab #1

** Use pencil to complete the table.

Fill out the chart with the physical properties determined from the lab: Mineral Identification Tests, then use the key for naming, use your book for the chemical formula (p. 918).

Rock Number	Color	Streak	Luster (metallic, dull, glassy)	Hardness (soft, medium, hard)	Density (g/cc)	Mineral Name	Chemical Formula	Family
#1					2.8		Complex Silicate	
#2					2.65		SiO ₂	
#3					2.7		CaCO ₃	
#4					7.6			
#5					2.2			
#6					5.0			
#7					5.2			
#8					5.3			
#9					2.7			
#10					2.7			
#11					2.6			

B-IV continued

1. The mineral calcite and the mineral quartz have a lot of similarities including color, density, luster, and streak. Why then can quartz scratch glass while calcite is so soft you can scratch it with your fingernail? Use at least 2 to 4 complete sentences to explain your answer.
2. List some similarities between hematite and magnetite. Explain why they are similar.
* _____
* _____

Explain why they are similar:

3. Thinking about all of the identification tests you have done today, why is it important for a geologist to use MORE THAN ONE test to accurately identify a mineral sample? Use at least 2 to 4 complete sentences to explain your answer.
4. Why is color a poor indicator of mineral identification?

B-V Mineral ID Lab #2

Perform the tests in the chart below. Match your test results with the description on the handout (or p. 918 of your text).

Mineral	Color	Streak	Luster	Hardness	TENNIS BALL CONTAINER NUMBER _____		
					Cleavage (Y or N) How many directions?	Other	Remarks
A Name: _____							
B Name: _____							
C Name: _____							
D Name: _____							

B-VI Computer Lab: Rocks

Questions:

When the main page opens, choose **Earth Materials**, then **Igneous Rocks**.

1. Frames 213- 218 Why does magma rise to the surface?
_____ What type of igneous rock does it produce when
it gets to the surface? _____ or _____
2. Frames 219- 226. Most magma never reaches the
_____. It crystallizes at great depths and forms
_____ or _____ igneous rocks.
3. Run frame 220 a few times and make sure you see the
process that brings intrusive igneous rocks to the surface.
Explain it in your own words- _____ Have
you ever been to any of the places in frames 221-226? _____
4. **Earth Materials: Igneous Textures** frames 227-235. View
the frames and then answer the following questions. You
may have to move back-and-forth (use "<<" and ">>" to do
this).
 - A. What is "texture" of igneous rocks? _____
What controls texture? _____
 - B. What does the term "aphanitic" mean? _____
What type of igneous rocks would have an aphanitic texture?
Intrusive or extrusive? _____
 - C. "Holey" igneous rocks are called _____. What
causes the texture? _____
 - D. "Phaneritic" texture indicates (intrusive or extrusive)
_____ igneous rocks because of the _____
crystals that cooled (slowly or quickly) _____.
 - E. What texture does obsidian have? _____ How did
it cool? _____ Is it intrusive or extrusive? _____
Frame 236-239 complete the "quizzes".
5. View frames 240-249. A porphyritic texture has _____
_____ crystals which means it cooled
frames (242-3) _____

Frames 249-254 do the "quizzes". Choose "I give up" if you
can't find the answer. Then go to **Frame 287** use the
"jump" command at the top right.

B-VI continued

6. Frames 287-292. What are the 2 types of weathering?
_____ and _____ How does breaking a rock
help speed up weathering? _____

7. "Jump" to frame 296. Why is shale the most common
sedimentary rock? _____

8. "Jump" to frame 303 and view through frame 305. What
are the two processes included in "lithification"?
_____ and _____ what types of rocks are
produced this way? (clastic or nonclastic) _____.

9. "Jump" to frame 349. Frames 349-351 why are
sedimentary rocks good for explaining the history of the
Earth? (YOW) _____

10. View frames 352-361 then go to frame 362 and try the
activity. Do activity on frame 365.
Then go to "Metamorphic Rocks" frame 367.

11. Frames 367-372 What types of rocks can become
metamorphic rocks? _____ Of the 3 "agents of
metamorphism" which is most important? _____

12. Frames 373-378. Name 4 ways rocks can become
metamorphic. 1- _____ 2- _____
3- _____ 4- _____

13. "Jump" to frame 384. What is foliation? _____
What causes it? _____
Frame 385 nonfoliated rocks contain only _____ so
they have no layers.

14. Frames 388-396 Try to identify the metamorphic rocks.

Try the "Rock Review" activity. **Go to main menu, Earth
Materials, "G" Rock Review!!!!!!!!!!!!!!**

B-VII Igneous Rock Lab

Gently dump the rocks from the tennis ball container. Find rocks labeled 1 through 8 and put them in order. SET ROCKS A AND B ASIDE UNTIL ASKED FOR. Use your magnifying glass to examine the rock's color and texture.

1. Complete the table below by placing the number of the rock in the appropriate space below: ONLY USE ROCKS 1 THROUGH 8

* NOTE: Obsidian is the only exception to the color rule, it's dark even though it is felsic!

Texture	Felsic	Mafic
Intrusive (phaneritic)	Granite	Gabbro
Extrusive (aphanitic)	Rhyolite	Basalt
Porphyry		Andesite
No Crystals	Obsidian	
Vesicular	Pumice	Scoria

Use rock names, not numbers, in all answers:

2. Based on what you learned in class, explain how granite forming deep within the Earth's crust results in large crystals?
 - a. How does the formation of gabbro compare to the formation of granite?
 - b. How is it different?
3. Using a magnifying glass, look at the crystal size of basalt. Explain the environment that would form these crystals?
4. Which of the rocks are extrusive (use the name of the rock not the number)? _____, _____, _____, _____ & _____
5. Near what type of **geologic** feature are extrusive igneous rocks found? _____

B-VII Continued

6. Explosive gases and liquids are an important part of lava. Which two of the rocks show evidence of gases present when they cooled? _____
What is your evidence? _____
7. Using a magnifying glass, look at obsidian. It cooled so quickly that no crystals were able to form. Explain a possible scenario where this could occur?
8. Dark minerals in rocks usually indicate higher concentrations of iron and magnesium and give the rock a higher density. Which are the mafic rocks? (Do not include obsidian in this group) _____,
_____, _____ & _____
9. Light colored igneous rocks usually indicate higher concentrations of (notes) _____,
_____ and _____. They have a _____ density than dark colored rocks. Light colored igneous rocks are called _____ or _____. Which are the felsic rocks? Obsidian, _____, _____, and _____.
10. Rocks that make up the continents are usually granitic, intrusive, lower density rocks. Which rock best fits that description? _____
11. Rocks that make up the ocean floor are usually basaltic, extrusive and have a higher density. Which rock best fits that description? _____.
12. Using a magnifying glass, look at Rock A. Rock A is called Diorite. Classify diorite by its texture and color and explain how diorite received these characteristics.
13. Using a magnifying glass, look at Rock B. Rock B is called Granite Pegmatite. Explain why this piece of granite has larger crystals than the other?
14. Draw the diagram of the volcano on page 100 of your textbook. To the best of your ability (be neat). Label where the following rocks could be found.
A. Rhyolite B. Granite C. Pumice D. Porphyry

B-VIII Igneous Rock Fudge

Follow the recipe below to prepare the fudge. Your group will receive specific instructions on how to cool the fudge (be sure to check the box below so you remember your groups instructions.) We are trying to simulate how cooling rates affect the growth of crystals (in this case, sugar crystals in fudge) in igneous rocks.

DIRECTIONS:

3/4 c Margarine
3 c Sugar
2/3 c Evaporated milk
1 pk BAKER'S Semi-Sweet Real Choc
7 oz KRAFT Marshmallow Creme
1 t Vanilla extract

1. MICROWAVE: In 4-quart, microwave-safe bowl, microwave margarine on HIGH (full- power) 1 minute or until melted.
2. Add sugar and milk; mix well.
3. Microwave on HIGH 5 minutes or until begins to boil, stirring after 3 minutes. Mix well; scrape bowl.
4. Continue microwaving 5-1/2 minutes; stir after 3 minutes. Mix well; scrape bowl.
5. Stir in chips until melted.
6. Add remaining ingredients; mix well.
7. Pour into greased 9-inch square pan or 13x9-inch baking pan.
8. Cool following your teachers instructions.

Your group will cool their fudge in the following manner (check one):

- _____ Take immediately from the last step in the directions and place in the freezer until cool.
- _____ Take immediately from the last step in the directions and place in the refrigerator until cool.
- _____ Take immediately from the last step in the directions and place on the counter until cool.
- _____ Take immediately from the last step in directions and place into the oven at 110°F (or lowest setting) for 1 hour then onto counter to cool.

Cut into squares.

Preparation Time: 10 minutes

Microwave Cooking Time: 12 minutes

B-IX Recipe: Pumice Candy

Igneous rocks are those formed from molten magma. Intense heat is involved. When students think of igneous rocks they almost immediately think of volcanoes and, they have probably had some experience with various volcano models. Using hard rock candy allows you to talk about the earth's molten interior and thin outer shell or crust. When the shell breaks this molten material pours out on the surface of the earth, sometimes forming or from volcanoes but other times in great rift zones like the Mid Atlantic Ridge. These candy making activities allow you to help your students better understand igneous activities in rift zones.

SeaFoam/Igneous Rocks: pumice and scoria

This is a variation of the first recipe that demonstrates the gas bubbles in lava flows.

Directions:

1. Combine in 2-3 quart pan and cook to 300°
 - 1 cup dark Karo Syrup
 - 1 cup white sugar
2. Remove from heat. Add:
 - 3 1/2 Tablespoons *SIFTED* baking soda
3. Stir in baking soda. Candy will begin to foam and greatly increase in volume.
4. Pour out onto foil covered cookie sheet. Cool. Cut or break into pieces to examine the interior and ENJOY!

(Adapted from a recipe designed by Judy Ruddock from Michigan Earth Science Teachers Association)

B-X Making a Sedimentary Rock

Materials:

- Al cup (used for baby tarts/cheesecake)
- Sand
- Epsom salt
- Beaker
- Hot plate
- water
- Incubator
- Pipette/eye dropper

Procedure:

1. Write your name and hour on the aluminum cup.
2. Heat 150 mL (1 cup) of distilled water to NEAR boil. You should NOT boil the water. The temperature should be consistent with hot tap water.
3. WHILE the water is heating, fill half the aluminum cup with sand.
4. Remove beaker from the hotplate. Turn the hotplate temperature to 1 and set aside.
5. Add 100 mL (1 cup) of Epsom salt. Stir until it is completely or ALMOST completely dissolved.
6. Using the pipette, SLOWLY add the Epsom salt-water mixture to the sand. You do not want to over saturate the sand. The sand should appear damp and you should NOT see excess water on top. *** If there is excess, use the pipette to remove the water. Squirt excess into beaker.
7. Place the cup into the incubator over night.
8. Answer the following questions, while you wait.

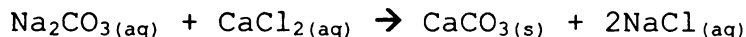
Questions:

1. What environments would you expect sandstone to form in?

Some of the most beautiful sandstone specimens in the world are found in Pictured Rocks in the Upper Peninsula. What does this tell you about Michigan's geologic history

2. What method of lithification was used in this lab, compaction, cementation or both? _____ Explain:
3. Use the rock cycle to describe the formation of quartz sandstone.
4. Explain how you can weather your sandstone so that you can get the sand back?
5. Provide an example of how this (#4) can occur in nature?
6. Besides the Epsom salt, what minerals that we have discussed in the past, can solidify sand into sandstone? Explain:

B-XI Making a Precipitate



Lab Pre-Questions:

1. What is a precipitate?
2. What does aqueous (aq) mean?
3. Make a prediction: Can mixing 2 clear liquids produce a solid?

Materials:

- 2 graduated cylinders
- CaCl_2 solution
- Na_2CO_3 solution
- 2 100 mL beakers
- Coffee Filter paper
- Funnel
- Wash bottle
- Bottle of the Works

Procedure:

1. Use a graduated cylinder to measure approximately 22 mL of CaCl_2 solution. Record the exact amount being used.
_____ mL
2. Use a graduated cylinder to measure approximately 11mL of Na_2CO_3 solution. Record the exact amount being used.
_____ mL
3. Pour the liquids from both graduated cylinders into a clean 100mL beaker. If you do not immediately see the formation of a precipitate, then gently swirl.
4. Gravity filter the white solid. This is done by folding a piece of coffee filter paper into quarters and making a cone. Place the cone inside your funnel. Hold the funnel over the second beaker and pour the solution into the center of the filter paper. Wash the sides of the 1st beaker with a small amount of distilled water from your wash bottle and filter this liquid through the filter paper. There will still be some white solid inside the beaker, but it is not worth the time and effort to continue the wash and filter process to remove it.
5. Tear a piece of paper towel off the roll and write your names/hour on the edge of the paper towel.
6. Carefully remove the filter paper (it will be very moist and fragile) from the funnel. Set it on the paper towel.
7. Clean your lab area and answer the questions below.

Question:

1. Calcium (Ca) is weathered down from plagioclase feldspar (called anorthite) in the igneous rock granite. The

B-XI Continued

released calcium reacts with carbonic acid (H_2CO_3) in water to form CaCO_3 (calcium carbonate). Using the rock cycle, explain the formation of limestone from the igneous rock granite. Use as many steps as necessary but you should have at least 3. You can draw it if you include explanations. Use the back of this sheet to explain your answer.

2. What test can we do to prove that the white powder is calcium carbonate? _____ Perform this test. What happened? _____ What mineral must be present? _____. What type (or types) of rock(s) did we simulate the formation of?
3. Explain how calcium carbonate can precipitate from water in nature?

B-XII Sedimentary Rocks

Separate the rocks into groups of clastic and nonclastic sedimentary rocks and place the number in the appropriate space. USE THE ROCK NAME, NOT NUMBER WHEN ANSWERING QUESTIONS.

Materials:

1. Sedimentary rocks 10-15
2. Sedimentation tube
3. Magnifying glass
4. Small bottle of "the Works"
5. If you perform an acid test, GOGGLES MUST BE ON!!!

CLASTICS

<u>Rock Number</u>	<u>Appearance/Texture</u>
_____ Conglomerate	pebbles, sand, silt, and clay
_____ Sandstone	sand-sized particles, sandpaper
_____ Shale	clay-sized particles, feels smooth

NONCLASTICS

<u>Rock Number</u>	<u>Appearance/Texture</u>
_____ Coquina	shell fragments, + acid test
_____ Bituminous coal	black, organic rock, - acid test
_____ Limestone	grayish-tan, chemical rock, positive acid test

1. Use the sedimentation tube. Shake it as hard and as fast as you can, but DON'T drop it! As soon as you finish shaking the tube, what is the first sediment to settle on the bottom? _____ Second? _____ Using your observations and what you have learned in class, explain why this would occur.

Using what you know about sediment size, explain why silt and clay do not settle right away?

2. The clastic sedimentary rock shale forms on the bottom of oceans where clay is deposited. Using what you know about the environment where sedimentary rocks form, describe the reason shale forms here.
3. Use a magnifying glass to study the conglomerate and the sandstone. Which one has the larger sediments?
4. _____ Describe the **difference** in the environment that formed the conglomerate verse the environment that formed the sandstone.

B-XII Continued

5. How does the fact that sedimentary rocks are produced in layers help geologists determine Earth history?

Using the clastic rocks above, choose one and describe how it may have formed and what it tells us about the surface of the Earth at that time.

6. Most clastic sedimentary rocks are made from broken down pieces of granite. Thinking about the Rock Cycle, describe a possible method that created sandstone starting from a piece of granite. (Use at least 3 steps). Feel free to draw it:

7. Label the diagram with the following underlined terms. Label the **bolded** on the diagram below:

- **fast** part of stream
- **slow** part of stream
- **still**, virtually NO motion
- sites where **clay**, **sand**, **gravel**, and **silt** would be deposited.



8. Look at the nonclastic rocks.

What happens in a positive acid test? _____.

"Positive" shows the presence of the mineral _____.

Which rocks have this mineral? _____ and _____.

9. Halite, aka salt, is an example of a nonclastic chemical sedimentary rock. It's an example of an evaporite. Provide a description of how halite might form-

10. Limestone is an example of a nonclastic sedimentary rock. It's an example of a precipitate. Explain how precipitates form -

B-XIII Metamorphic Rock Lab

Separate rocks 16-21 into foliated and non-foliated metamorphic rocks. Match the rock numbers with the descriptions below. **You do not have to label rocks 1,11,13 and 14.** Use the Rock Name, NOT the number.

Materials:

- Bag of meta rocks 16-21 with rocks 1,11,13,14
- Magnifying glass
- Squirt bottle of "the Works"
- WEAR GOGGLES DURING ACID TEST

Foliated Metamorphic Rocks: Appearance/Texture

___ slate	Appears flattened with thin layers. Parent rock is shale (11)
___ mica schist	Appears platy. Parent rock is slate
___ gneiss	Parent rock is granite (1)

Non-foliated Metamorphic Rocks: Appearance/Texture

___ marble	Positive acid test. Parent rock is limestone (14)
___ quartzite	Negative acid test. Parent rock is sandstone (13)
___ anthracite	Negative acid test. Parent rock is coal

Lab Questions:

1. Compare gneiss with granite (rock #1). What evidence can you observe that suggests that granite is the parent rock to gneiss?

Thinking of the rock cycle, start with a piece of granite and explain the process that formed gneiss.

2. Compare slate to shale (rock # 11). What evidence can you **observe** that suggests shale is the parent rock of slate?

Recall the rock cycle. Starting from the igneous rock granite, describe a possible process that formed the metamorphic rock slate. Feel free to draw it:

Reminder: shale is a sedimentary rock formed from the accumulation of clay sediments. THINK ABOUT IT!!!

3. What test could you perform to prove marble is related to limestone (rock #14)? _____ Go ahead and perform the test. What did you observe? _____
What mineral can you conclude is present in each rock? _____ Recall the changes that occur

B-XIII continued

during metamorphosis (what happens to the rock), explain why marble looks very different from limestone.

4. Compare quartzite and sandstone (rock #13). Notice how quartzite looks as if the sand grains have been "welded" together. Using your knowledge the process of rocks becoming metamorphic, how could this have happened?
5. Compare marble with gneiss. What causes some metamorphic rocks to foliate while others do not?

Use your notes and the textbook to answer the following questions:

1. How are metamorphic rocks formed?
2. What is regional metamorphism?
3. What 2 things can cause the pressure that produces metamorphic change?
 1. _____
 2. _____
4. What role does water play in metamorphic change?
5. What does the squeezing of the rock from pressure do to the rocks crystal grains?
6. What does heat and chemicals do to the rocks?
7. Explain the steps in the metamorphism of shale?
 - a.
 - b.
 - c.
 - d.
8. Explain contact metamorphism?
9. Compare the amount of rock changed by contact metamorphism to regional metamorphism-

B-XIV The Rock'n Brainstorm

Directions:

1. Log on to your computer. One person per computer.
2. Open up the "Inspiration 7.5" program located either on the desktop or the Novell Application window.
3. When the program opens, a bubble with the words "main idea" will be highlighted and found in the center of the application window. In that bubble write "Rocks". You can place that bubble anywhere on the screen by clicking and dragging. I would place it on the top-center of the screen.
4. With your cursor arrow, click on the screen about 2 inches directly below your "Rocks" bubble. A large plus symbol should mark your spot.
5. Find the "Basic" window application on the left side of the screen. Click on the top-left bubble. A new bubble should have formed where your plus sign was on the screen. Name that new bubble "Sedimentary Rocks"
6. Find the "link" icon on the toolbar at the top of the page and click on it. Now, click 1 time on the "rocks" bubble and then 1 time on the "sedimentary rocks" bubble. This will create an arrow that connects the 2 bubbles. It should point towards the "sedimentary rocks" bubble.
7. You should notice a box made out of dashed lines on the arrow. You can write the definition of sedimentary rocks in this box, by clicking on it and filling it in. Do it now!!!
8. For igneous rocks and metamorphic rocks, repeat steps 5 through 8. You should put igneous on one side and metamorphic on the other.
9. Put a box from the "basic" menu in the upper right hand corner. Put your name and hour in this box.
10. From the file menu in the top left side, choose save as. Save this as "rocks" in your H:drive
11. From the file menu, choose print. Please do not print in color.
12. On the taskbar, click on the "Outline" icon. This should create an outline of all of your bubbles.
13. This is the beginning of a great study tool!

Part 2: Individual Rock Pages

1. *You will follow the same format as above except now your title bubbles will be the 3 rock types, SO you will have 3 pages. One for each rock type.*

B-XIV Continued

2. I expect all of the following **terms, definitions, and examples** in your brainstorm. Use the sedimentary brainstorm we did in class together as a reference. (You can copy that example straight on to your computer). Do the same for all of the rock types. You will notice I added some terms for the sedimentary rocks, add those to your computerized brainstorm.
3. When you are done with each rock type, save it to your H-drive and print it out.

Sedimentary Rocks: terms, definitions, and examples

- | | | |
|---------------|-------------|-----------------|
| 1. Clastic | 3. Chemical | 5. Precipitates |
| 2. Nonclastic | 4. Organic | 6. Evaporites |

Igneous Rocks: terms, definitions, and examples

- | | |
|---------------------------|----------------------|
| 1. Mafic (Basaltic) | 7. Lava |
| 2. Felsic (Granitic) | 8. Magma |
| 3. Intrusive (Phaneritic) | 9. Vesicular Texture |
| 4. Extrusive (Aphanitic) | 10. Texture |
| 5. Porphyritic | 11. Color |
| 6. Glassy Texture | |

Metamorphic Rocks: terms, definitions, and examples

- | | |
|--------------------------|-----------------------------|
| 1. Contact Metamorphism | 5. Foliated Rocks |
| 2. Regional Metamorphism | 6. Nonfoliated Rocks |
| 3. Parent Rock | 7. Products of Metamorphism |
| 4. Daughter Rock | 8. Positive Acid Test |

Rock Cycle: Make a rock cycle starting from granite and ending with quartzite. Granite is an igneous rock made from quartz and feldspar. Quartzite is a metamorphic rock made entirely from quartz. You can use as many of the terms below as you need. You need at least 5 steps.

- | | |
|------------------------------|----------------------|
| 1. Weathering/erosion | 7. sorting |
| 2. Deposition | 8. heat and pressure |
| 3. Compaction/cementation | 9. uplift |
| 4. sandstone | 10. melting |
| 5. sediments | 11. dissolving |
| 6. solidifying/crystallizing | 12. precipitation |

Feel free to add more bubbles! The more, the merrier!

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