GROUND**RULES**

GEOLOGY

Geology
AGES 15 - 18

INTRODUCTION

As the demand for mined minerals increases, everyone—from students, to miners, to governments and global corporations—must understand how to work together to meet those needs while protecting the world in which we live.

Ground Rules: Mining Right for a Sustainable Future is a documentary film created by Caterpillar and Science North. It follows the development of new and operating mines as geologists, engineers and mine managers tackle complex problems. It draws on the experiences and achievements of modern mine sites to illustrate creative and core concepts of sustainable development and social responsibility.

This set of lesson plans was developed by Science North, commissioned by Caterpillar to accompany the *Ground Rules* film. It provides a tool for educators to further examine the themes and concepts presented in the film through a series of "hands-on" classroom activities. It introduces students to the various phases involved in mining, different types of mines, how ore is processed, how mineral deposits were formed, how modern mines can operate safely and sustainably, and why minerals are important to our everyday lives. This material also introduces students to a wide variety of mining careers.

The lesson plans have been designed to broadly complement the curriculum objectives for the United States, Canada, and Australia. However, the lesson plans are not region-specific and can be used by educators throughout the world. All of the lesson plans have strong linkages to the earth science curriculum, but many of the activities incorporate additional linkages to math, chemistry, data management, mapping, environmental studies, electricity, magnetism and problem-solving. The lesson plans can be easily adapted to meet specific local curriculum goals.

In each lesson plan, an introductory section provides the appropriate film chapter reference and describes the key concepts for the lesson. One or two activities are then described in a step-by-step format. These activities include experiments, demonstrations, games, building activities, and research projects. The lesson plans end with a discussion section that provides possible follow-up topics and questions for classroom discussion. Each lesson plan also includes curriculum linkages, a vocabulary list, a materials list, and approximate timelines for completion of each section. Teacher answer sheets or data sheets are appended, where appropriate.

The lesson plans are organized into five broad themes: Geology; Mining; Mining Processes; Ore Processing; and Minerals and Everyday Life. The lesson plans are further sub-divided into three age categories: 11 to 13 years; 13 to 15 years; and 15 to 18 years. In many cases, the same topics are covered in each age category. However, lesson plans in the older age categories contain additional activities, alternative age-appropriate activities, and/or enhanced complexity.

Theme: Geology

This theme covers the key concepts of geology that are important to mining. The younger students will learn how to identify some common minerals using five properties. Older students will learn about additional mineral identification properties and how to use mineral tests to distinguish between similar looking specimens. Younger students will learn how the process of erosion moves soil and rock, exposing valuable minerals in the underlying deposits, such as gold or diamonds. All students will explore layering and geologic structures in the playdough tectonics lesson, with increasing complexity for each age group. Students will discover how sedimentary rocks are formed and will make their own sandstone, conglomerate and limestone samples. Older students will also study soil porosity and create and measure crystal growth. The 15 to 18 year-old students will explore processes involved in the recycling of rocks.

Ground Rules – Online Viewing and Learning Resources

As noted, these lesson plans are designed to be used with *Ground Rules: Mining Right for a Sustainable Future*. Multiple options are available for using the film in your classroom:

- **Order a free copy of the Ground Rules DVD**, containing both the English, Spanish and French versions of the film, from the Caterpillar web site, http://www.cat.com/groundrules.
- **View the full-length version of the film** in English, Spanish, French, as well as English with Chinese subtitles, online at http://www.cat.com/groundrules.
- **View individual chapters of the film** in English, Spanish and French, as referenced by individual lesson plans, on our You Tube channel, http://youtube.com/catgroundrules.

The full set of these lesson plans is available at http://www.cat.com/groundrules, and additional information and activities will be posted there as they become available.

Finally, follow *Ground Rules* online! Share your classroom experiences, feedback and ideas with us. Post photos of your projects and tell us about your successes!

Facebook: http://tinyurl.com/yzhxrva

Twitter: http://twitter.com/catgroundrules

About Caterpillar

For more than 80 years, Caterpillar Inc. has been building the world's infrastructure and, in partnership with its worldwide dealer network, is driving positive and sustainable change on every continent. With 2008 sales and revenues of $51.324 billion, Caterpillar is a technology leader and the world's leading manufacturer of construction and mining equipment, diesel and natural gas engines and industrial gas turbines. More information is available at www.cat.com.

About Science North

Science North, which opened in 1984 and is located in Greater Sudbury, is Northern Ontario's most popular tourist attraction and an educational resource for children and adults across the province of Ontario, Canada. Science North's drawing power lies with its unique approach to learning. The science centre has become world-renowned for its unique brand of hands-on science education and entertainment experiences which involve people in the relationship between science and everyday life.

Science North's attractions include a science centre, IMAX® theatre, butterfly gallery, special exhibitions hall, a digital Planetarium, and Dynamic Earth – a second science centre that offers visitors an up-close look at mining and the geological forces that continually shape the Earth. The same philosophies used to teach visitors about science at Science North are incorporated into every exhibit at Dynamic Earth, which first opened in 2003. This mining and geology centre combines above and underground experiences that allow visitors to work and play with real mining equipment and technologies. The site is also home to Sudbury's famous Big Nickel.

An agency of the provincial government of Ontario, Science North is overseen by the provincial Ministry of Culture. More information is available at http://sciencenorth.ca.

CRYSTAL FORMATION FROM MINERALS

Description

Students will observe the process of crystal formation, measure crystal growth, learn to distinguish between stalactites and stalagmites and learn how these structures are formed naturally in limestone caves.

VOCABULARY:

1. Crystal
2. Atom
3. Molecule
4. Solution
5. Ion
6. Reaction
7. Precipitate
8. Dependant variable
9. Independent variable
10. Line graph
11. Stalactite, stalagmite
12. Limestone, calcite

MATERIALS:

- 1.2 oz (35.5 mL) bottle of sodium silicate
- 1.4 oz (41.4 mL) glass jar (baby food jar)
- Water
- 1 vial of mixed sulfate crystals (blue copper sulfate, green nickel sulfate and white magnesium sulfate)
- Safety goggles and gloves
- Tweezers
- Graph paper
- Pencil and colored pencils
- Rulers
- Access to Internet or text book references

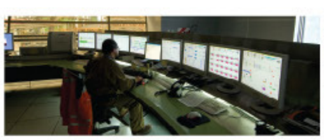
Introduction (Length: 15 minutes)

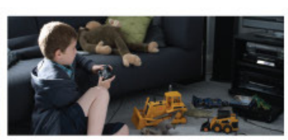
Ask the students what a crystal is. In crystals of any kind, atoms or molecules join together in a pattern that repeats itself over and over to create a specific shape. The crystals grow by repeating the exact same pattern continuously.

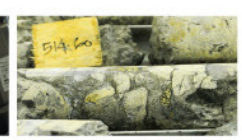
Ask the students if they know what stalactites and stalagmites are. Where do you find them? They are typically found in limestone caves. Stalactites form on the roof of a cave and grow downwards, while stalagmites form on the floor and grow upwards.

Explain that there are a number of ways to create crystals. In this activity, they will be creating crystals of soluble metallic salts. When the salts come into contact with the sodium silicate solution the metal reacts and the reaction creates the colored precipitant crystals. These crystals will grow upwards forming stalagmites.

Warn students that some of the chemicals used are skin irritants, corrosive, or can be toxic. The crystals should not be handled directly, therefore gloves or tweezers should be used.





Activity I (Length: 30 minutes)

The objective of this activity is to create crystal stalagmites.

1. Put on safety gloves and goggles.
2. Open the bottle of sodium silicate and pour the contents into the glass jar.
3. Fill the rest of the space in the jar with water.
4. Replace the cap on the jar making sure it is tightened securely. Vigorously shake the jar.
5. Open the vial of crystals and gently shake them into the sodium silicate solution so the crystals fall to the bottom of the jar. Alternatively, you can place the crystals where you want them to grow using tweezers. Quickly replace and tighten the cap.
6. Record the time on your data sheet.
7. At regular time intervals, record the length of one copper silicate stalagmite (green), one nickel silicate stalagmite (blue) and one magnesium silicate stalagmite (white) in a data table along with the time of measurement. You will have to take the measurements from the outside of the jar. Continue taking measurements until the crystals stop growing.
8. Create a line graph on graph paper showing the rate of crystal growth over time. Use three colors of lines to represent the three colors of crystals.

Activity II (Length: 30 minutes)

The objective of this activity is to explore the chemical reactions that take place when stalactites and stalagmites grow in limestone caves. Using the Internet or appropriate text book or encyclopedia references, answer the following questions:

1. What is the most common type of mineral found in limestone? What are two other minerals that are sometimes found in limestone?
2. What is the chemical formula of the most common mineral?
3. How does limestone form?
4. Explain how stalactites and stalagmites are formed in limestone caves.
5. What chemical is formed in the liquid solution that drips into the cave?
6. What is the chemical formula for the reaction that creates the liquid solution that drips into the cave?
7. What is the chemical formula for the reaction that produces the crystals?
8. How much do limestone cave crystals typically grow in a year? What controls the rate of growth?

Discussion (Length: 15 minutes)

Activity I:
Discuss the results of the experiment. Look at the line graphs. Which crystals grew longer? Which crystals formed faster? Which type of crystal was more abundant? Was the growth rate constant or did it vary over time?

Explain how the crystals formed. Certain metal salts, especially the transition metals (groups 3 to 12 on the periodic table), form precipitates in the sodium silicate solution. As the metal salt dissolves, the resulting solution is less dense than the sodium silicate. The difference in density causes the product, an insoluble metal ion silicate, to rise up through the solution. This is why the crystal grows upwards. As it reacts with the silicate anion, stalagmites form from the bottom of the jar upwards. The surfaces of the silicates are semi-permeable, allowing water to travel though. Water pressure causes the membranes to burst, allowing more metal ions to react. This process repeats itself until the metal salt is fully dissolved, creating a crystal structure.

If students want to bring their crystal gardens home, carefully pour out the silica solution and fill the jar with water.

Activity II:
Review the answers to the questions.

Visit cat.com/groundrules for more information, to provide feedback, to view the *Ground Rules* film on-line, or to order a copy of *Ground Rules* on DVD.

Activity II - Answers

1. Calcite is the most common mineral found in limestone. Limestone also frequently contains dolomite and aragonite.
2. $CaCO_3$ (calcium carbonate).
3. All limestone forms from the precipitation of calcium carbonate from water. It can be formed with the help of living organisms or without. The process of formation of stalactites and stalagmites in limestone caves occurs without the help of living organisms.
4. The key ingredient to making stalactites and stalagmites is water. When rainwater trickles through cracks in the rocks, it picks up carbon dioxide and minerals from the limestone and carries them through into the cave. Once this solution comes into contact with the air inside the cave, it starts to form into calcite crystals and precipitate around the crack. As water continues to drip, more calcite crystals form on top of the previous ones and the stalactite grows in length. Some of the water drips onto the floor of the cave and creates stalagmites.
5. Calcium bicarbonate or $Ca(HCO_3)_2$.
6. $CaCO_3 + H_2O + CO_2 \rightarrow Ca(HCO_3)_2$
7. $Ca(HCO_3)_2 \rightarrow CaCO_3 + H_2O + CO_2$ (the opposite of the equation in #6)
8. Stalactite and stalagmite growth is very slow. An average growth rate is approximately 0.005 inches (or 0.1 mm) a year. The rate of the flow of water into the cave controls the growth rate.

GEOLOGY	AGE: 15 TO 18	LENGTH:2.25HR	CURRICULUM: earth science, classification

MAKING SANDSTONE, CONGLOMERATE AND LIMESTONE

Description

Students will explore the processes that form sedimentary rocks and model different classes of sedimentary rocks.

VOCABULARY:

1. Classification
2. Sedimentary rocks
3. Sandstone
4. Conglomerate
5. Limestone
6. Grain size
7. Porosity

MATERIALS:

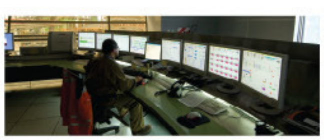
- Dry sand, dry cement and dry plaster
- Cementing solution (2 parts water, 1 part Epsom salt)
- Small paper cups and 2 shoeboxes
- Mixing sticks
- Garbage bags and sandwich bags
- Water
- Small rocks and pieces of shells
- Magnifying glasses
- Samples of different types of sedimentary rocks and a few igneous or metamorphic rocks
- Graduated cylinder and beaker
- Calculators

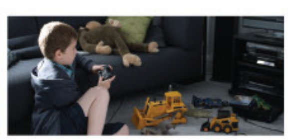
Introduction (Length: 15 minutes)

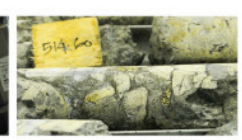
Display a variety of different types of sedimentary rocks (and one or two igneous or metamorphic rocks) at the front of the class. Ask the students what kind of rocks these are? Are they all the same kind? Ask them to find the one or two rocks that are different than the rest. Discuss the differences between sedimentary, igneous and metamorphic rocks.

Have the students look at the sedimentary rocks. Explain that in addition to the three major rock classifications, there are also ways to classify or group types of sedimentary rocks.

Explain that in this activity, they will be making three different types of sedimentary rocks. They will also be exploring the ways in which sedimentary rocks can be classified.





Activity I (Length: 30 minutes + 30 minutes a few days later)

The objective of this activity is to make a piece of sandstone, conglomerate and limestone.

Sandstone:
1. Fill a small paper cup halfway with sand.
2. Slowly add the cementing solution until the sand is wet all the way through, but the water isn't pooling.
3. Put the sandstone in a warm place until the top is dry (overnight).
4. The next day, invert the cup on top of a paper towl. Gently remove the cup. It will still be wet, but should be dry enough to hold its shape. Do not handle the sandstone until it is completely dry (approximately 2 to 3 days).

Conglomerate:
1. Line a shoebox with the plastic garbage bag.
2. Add one cup of dry cement, one cup of dry sand, and one cup of cold water. Mix thoroughly with a stick.
3. Add many rocks to the mixture and mix thoroughly.
4. Pour into small cups lined with sandwich bags, one for each student.
5. Place cups in a warm area to dry (approximately 2 to 3 days).

Limestone:
1. Line a shoebox with the plastic garbage bag.
2. Add plaster and water. Mix thoroughly with a stick.
3. Add shells and mix together with plaster.
4. Pour into small cups, one for each student.
5. Place cups in a warm area to dry (approximately 2 to 3 days).

Follow-up (2 to 3 days later):
1. Students should remove the conglomerate and limestone from the cups. They should place the sandstone, conglomerate and limestone in a row in front of them.
2. Make a data table with three coloumns, one for each type of rock. Each student should examine their samples with a magnifying glass and compare and contrast the properties of the three rock types. What is the same? What is different?
3. Draw a rough diagram of each rock sample.

Activity II (Length: 30 minutes)

The objective of this activity is to measure the porosity of sand.

1. Measure 50 mL of sand in a graduated cylinder.
2. Place the dry sand in a small beaker.
3. Measure 100 mL of water in a graduated cylinder. Slowly add the water to the sand. Where is it going?
4. Continue to add water to the sand until the sand is completely saturated with water. Do not overfill the sand with water.
5. Determine how much water was used to fill the air spaces between the sand particles. This is the pore volume of the sand.
6. Calculate the porosity of the same as follows:

$$\text{Porosity (\%)} = \frac{\text{pore volume of sand (mL)}}{\text{total volume of sand (mL)}} \times 100\%$$

Discussion (Length: 30 minutes)

Activity I:
Discuss the observations made by the students. What properties were different between rock types? What properties were the same? Explain that types of sedimentary rocks are typically classified on the basis of grain size and what they are composed of.

Sandstone is a medium-grain rock with grain sizes from 1/16 mm to 2mm in diameter. It is formed by cementing sand grains together.

Conglomerate is a course-grain sedimentary rock with grain diameters larger than 2 mm. It is formed by cementing rounded gravel pieces together.

Where does the “cement” come from in nature? Solutions of dissolved minerals like calcium carbonate may cement particles together. In the sandstone experiment, the Epsom salt (type of mineral) took the place of mineral deposits found in water that bond the sediment together.

Ask the students what is different about limestone compared to sandstone and conglomerate? Limestone is not formed like other sedimentary rocks because it is not cemented together. It is chemically bonded together. For this reason, limestone does not form in layers. Why did the limestone sample contain shells? Explain that limestone is formed in aqueous environments. It is often found in warm shall seawaters and is a common type of rock for finding fossils.

Discuss the other classifications of sedimentary rocks: shale, gravel, coal, till and topsoil.

Activity II:
Where did the water go when it was poured into the sand? How much water was used to fill the spaces? What was the porosity of the sand? Discuss the relationship of this experiment to the formation of sedimentary deposits. As much as 40 to 50% of the total volume of a sedimentary deposit may be filled with water.

What happens to the water when these sedimentary deposits turn into rock? As layers of sediment accumulate one on top of the other, the lower layers are subjected to increasing pressures and temperatures. Water contained in the pore spaces between the grains of sediment gets squeezed out and slowly carries dissolved minerals through the rock as it escapes upwards. These dissolved minerals often precipitate in the colder layers above and act as a cement, binding the grains of sediment together to form rock.

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GROUNDRULES

GEOLOGY | AGE: 15 TO 18 | LENGTH: 2 HR | CURRICULUM: earth science, mineral ID

MINERAL IDENTIFICATION

Description

Students will explore some of the physical properties of minerals and how these properties can be used to identify minerals.

VOCABULARY:

1. Mineral
2. Inorganic
3. Crystal
4. Element
5. Magnetism
6. Hardness
7. Streak
8. Cleavage
9. Fracture
10. Effervescence

MATERIALS:

- *Ground Rules* film
- Mineral identification key (provided)
- Mohs hardness scale (provided)
- Mineral Identification Table (provided)
- 5+ numbered mineral samples (good quality)
- Hand lens or magnifying glass
- Streak plates
- Copper pennies
- Steel files or nails
- Bar magnets
- Diluted hydrochloric acid/vinegar & eyedropper
- Glass microscope slides
- Safety goggles and gloves

Introduction (Length: 20 minutes)

Ask students what a mineral is. Minerals are solid, inorganic substances that occur naturally and have specific structures and chemical compositions. Minerals are present in rocks and can be extracted by mining in order to make all of the things we use in our everyday lives.

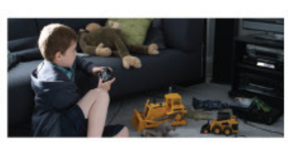
Watch Chapter 3 “Mining and the Modern World” of the *Ground Rules* film.

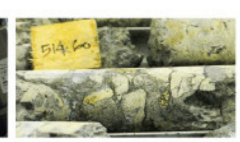
Ask students if they know how to recognize a specific mineral from another. You can tell the differences between minerals by looking for certain properties. Because each mineral is unique both chemically and structurally, each has its own set of physical, optical and structural properties, which aid in its identification. Chemistry refers to the basic building blocks that the mineral is made of. Optical properties refer to the way a mineral looks and what light does when it shines on it. Physical properties such as hardness and streak can be tested easily.

Discuss some of the common physical properties of minerals that can be tested to identify a mineral. These are color, luster, cleavage, streak, hardness, magnetism and effervescence.

Color is often the first property you notice about a mineral, but it may not be the most diagnostic feature. Often color can be misleading because some minerals have a variety of colors. Therefore, it should be used in conjunction with other





characteristics.

Luster is a description of the way the surface of a mineral reflects light. The easiest distinction to make is whether a mineral has metallic or non-metallic luster. Metallic minerals will have a luster similar to aluminum foil or jewellery. If the mineral is non-metallic, its luster can be further described as:

- Vitreous (like glass)
- Pearly (like a pearl)
- Waxy (like wax)
- Resinous (like resin)
- Greasy (like an oiled surface)
- Earthy or dull (no real sheen on the surface)
- Adamantine (brilliant, sparkling, gemlike)

Cleavage is the tendency of a crystal to break along flat planar surfaces. Cleavage is related to planes of weak chemical bond strength within the mineral. Cleavage is characterized by the number of cleavage planes and angles that the cleavage planes form. Cleavage is also characterized by how well the mineral cleaves (i.e. perfect, good, fair, or poor). Some minerals do not have cleavage. Instead, they fracture into jagged pieces.

Streak is the color of particulate dust left behind when a mineral is scraped across an abrasive surface. Streak color is more reliable than surface color as an indicator. The streak color will be constant, but the surface color may vary.

Hardness is a measure of the mineral's resistance to scratching or abrasion. It is measured using the Mohs Hardness Scale. This is a scale that measures the hardness of minerals relative to each other. The scale ranges from 1 to 10, with 1 being the softest and 10 being the hardest. A mineral should be able to scratch any mineral with a lower hardness number and can be scratched by any mineral or material with a higher hardness number. The following simple tools with known hardness values can be used to determine mineral hardness:

- Fingernail – hardness of 2-3
- Copper penny – hardness of 4-5
- Steel file/nail – hardness of 5-6
- Glass – hardness of 5-6

Magnetism identifies specific iron rich minerals. Only a few minerals such as magnetite or pyrrhotite are magnetic.

Effervescence results when weak acid is applied to some minerals that contain calcium carbonate. Carbon dioxide is released in this reaction and the acid will bubble on the surface of the mineral.

Explain that these are just some of the properties used to identify minerals. Geologists use many more properties to definitively identify a mineral.

Activity I (Length: 50 minutes)

The objective of this activity is to identify 5 mineral samples by testing various physical properties.

Preparation:

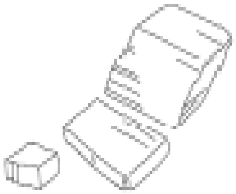
1. Choose 5 high quality mineral samples that can easily be identified by color, luster, cleavage, steak, hardness and magnetism. Some good mineral samples to use are: magnetite, hematite, talc (soapstone), quartz, chalcopyrite, pyrite, feldspar.
2. Prepare five mineral identification stations. Each station should have a numbered mineral, a Mineral Identification Table (for recording answers), a streak plate, a hand lens, hardness tools, a magnet, a small bottle of acid, safety gloves and goggles.
3. Divide the class into five groups. One group should be at each station to start.
4. Each group will have 10 minutes to determine the mineral properties for that sample. Then the groups will rotate to the next station and do the same for the next mineral, and so on. The activity is finished when all groups have visited each station.

Activity:

1. Color: Look at the mineral and decide what color(s) are present on the mineral surface. Write the color(s) in the appropriate spot in the Mineral Identification Table.

2. Luster: Observe how your mineral reflects light. First decide whether your mineral has a metallic or non-metallic luster. Does it sparkle when light reflects off of its surface? Does it look like a metal? If yes, then it has a metallic luster. If it is dull or shiny, but not like a metal, then it has a non-metallic luster. If the luster is non-metallic, try to further classify it as dull, earthy, waxy, pearly, vitreous, resinous or adamantine. Record the luster on the Mineral Identification Table.

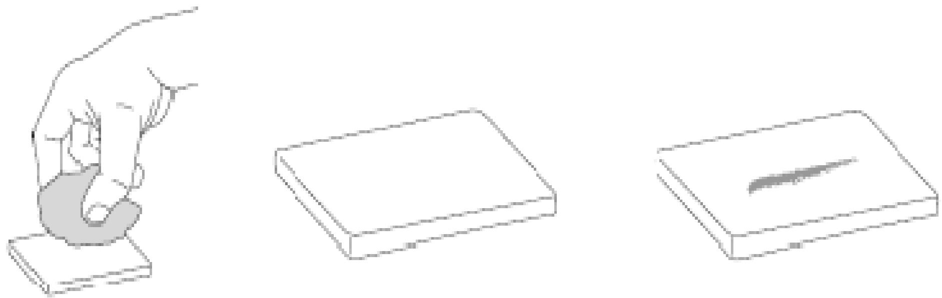
3. Cleavage: Look at the broken surfaces of your mineral with a hand lens. How does your mineral look on the surfaces where it has been broken? Did the mineral break along flat surfaces? If yes, then your mineral has cleavage. If no, then your mineral does not have cleavage. Write "yes" or "no" in the cleavage box on the Mineral Identification Table. If the mineral does not have cleavage, it will fracture into jagged pieces as shown below. If the mineral has cleavage, look more closely to see how many directions it cleaves in and how well it cleaves (perfect, good or poor). Add these descriptions to the Mineral Identification Table.



Cleavage

Fracture

4. Streak: Hold the streak plate on the table with one hand. Grasp the mineral in your other hand, press it firmly against the streak plate and pull it towards you to make a streak as shown below. If you press too lightly, it will not streak properly. Record the color of the streak in the streak box on the Mineral Identification Table. If no streak is visible on the streak plate, record "none". Try a couple of different surfaces of the mineral to make a streak.



5. Hardness: Conduct a series of tests with hardness tools to identify the hardness range for your mineral. Begin with the softest tool, your fingernail, and proceed up to glass. Each time evaluate whether your mineral is harder or softer than the material you are attempting to scratch. If the hardness tool can scratch you mineral, your mineral is softer than that tool. If the mineral can scratch the hardness tool, your mineral is harder than the tool. You may have to use a hand lens to see the scratch. True scratches do not rub off with your finger. Look up the hardness values of the hardness tools and record whether your mineral is greater than or less that those values in the Mineral Identification Table.

    a. Fingernail test: Try to scratch the mineral with your fingernail. If your fingernail scratches the mineral, find the hardness of a fingernail on the hardness scale and record that the mineral's hardness is less than that number in the box on the Mineral Identification Table and proceed to Step 7. If your fingernail does not scratch the mineral, go to b.

    b. Penny test: Attempt to scratch a copper penny with your mineral. If the copper penny does not scratch, the penny is harder than your mineral. Find the hardness of a copper penny in the hardness scale and record that the mineral's hardness is less than that number and proceed to Step 7. If the mineral scratches the penny, go to c.

    c. Steel file/nail test: Attempt to scratch a steel file or nail with your mineral OR you can try to scratch your mineral with the file or nail. If the mineral does not scratch the file/nail OR the file/nail scratches the mineral, your mineral is softer than steel. Find the hardness number of the steel file/nail on the scale and record that the mineral's hardness is less than that number and proceed to Step 7. If the mineral is harder than the steel nail/file, go to d.

    d. Glass test: Attempt to scratch a glass plate with your mineral. If the mineral scratches the glass plate, record that the mineral has a hardness greater than the hardness of glass. If the mineral cannot scratch the glass plate, record that its hardness is less than the hardness of glass.

6. Magnetism: Hold a bar magnet next to your mineral. If the magnet moves toward the mineral, write "yes' in the magnetic box on the Mineral Identification Table. If not, record "no".

7. Effervescence: Put on safety goggles and gloves. Add a drop of diluted hydrochloric acid or vinegar onto the mineral. Examine the reaction using a hand lens. If the mineral fizzes or bubbles, the mineral is effervescent. If there is no reaction, the

mineral is not effervescent. Record "yes" or "no" in the box on the Mineral Identification Table.

8. Move to the next station and repeat steps 1-8. Continue until all five minerals have been tested.

9. Compare your test results to a Mineral Identification Key and try to identify the five mineral types.

Activity II (Length: 20 minutes)

The purpose of this activity is to further explore how mineral identification tests can help to distinguish between similar looking samples and how color is not the best diagnostic feature.

a. Give each group two numbered samples (not ones used previously) that look very similar based on visual observation alone, but can be distinguished based on mineral identification tests. For example, calcite and quartz, or pyrite and chalcopyrite. Each group should complete all of the tests described in Activity I and determine the mineral type of each sample. What was the one diagnostic test that was the best for distinguishing between the two mineral types?

AND/OR

b. Give each group two numbered samples (not ones used previously) of the same mineral type that are different colors. For example different colored quartz samples. Each group should complete all of the tests described in Activity I and determine the mineral type of each sample. The students may get frustrated because they have determined the same mineral type for both samples, but they look like different samples. Remind them that the same mineral type can be a variety of colors in nature.

Discussion (Length: 20 minutes)

Activity I:
Review the answers with the class and see how many samples each group determined correctly. If there were some samples that were difficult to determine, compare the test results to the mineral identification key, note which properties were identified incorrectly and retest those properties. Which properties were the most helpful for identifying each mineral sample? Which property was the least helpful? Which mineral was the easiest to identify?

Activity II:
What was the best diagnostic test to distinguish between the two samples? Why is it important to do the diagnostic tests to identify minerals, rather than just identifying the sample visually? Emphasize the fact that surface color is not a good diagnostic feature because many different minerals can exhibit the same color and a given mineral type may have a variety of colors.

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Mineral Identification Key (Some Common Minerals)

Mineral	Color	Luster	Cleavage	Streak	Hard-ness	Magnetic	Efferve-scence
Bauxite	red, brown, yellow	earthy, dull	no	light brown, white	1-3	no	no
Calcite	varies(1)	vitreous, pearly	yes (perfect, 3 directions)	white	2.5-3	no	yes
Chalcopyrite	yellow-gold	metallic	yes (poor, 1 direction)	greenish-black	4	no	no
Dolomite	varies(2)	vitreous, pearly	yes (perfect, 3 directions)	white	3.5-4	no	no
Feldspar	varies(3)	vitreous, pearly	yes (90° angle)	white	6	no	no
Fluorite	varies(4)	vitreous	yes (perfect, 4 directions)	white	4	no	no
Garnet	white to dark gray, red	vitreous, pearly	no	none	6.5	no	no
Hematite	red-brown, gray, black	metallic	no	reddish-brown	5-6(6)	no	no
Hornblende	dark green, black	vitreous, dull	yes (perfect, 2 directions)	none	5-6	no	no
Magnetite	black	metallic	no	black	6	yes	no
Pyrite	yellow-gold	metallic	no	greenish-black	6	no	no
Pyrrhotite	yellow-gold	metallic	no	dark gray-black	3.5-4.5	yes	no
Quartz	varies(5)	vitreous	no	white	7	no	no
Talc	gray, white	pearly, greasy	yes (perfect, 1 direction)	white	1	no	no

(1) white, colorless, brown, green-black
(2) white, colorless, pink, brown, gray
(3) pink, gray, white, red, green, blue, colorless, black
(4) white, colorless, purple, pink, yellow, brown
(5) light green, purple, yellow, colorless
(6) may appear softer

Mohs Hardness Scale

Mineral Type	Hardness	Hardness Tool Test
Talc	1	scratched by fingernail
Gypsum	2	
Calcite	3	scratched by copper penny
Fluorite	4	scratched by steel file/nail
Apatite	5	
Feldspar	6	scratches glass
Quartz	7	
Topaz	8	
Corundum	9	
Diamond	10	

Mineral Identification Table

Property	Sample Number				
	1	2	3	4	5
Color					
Luster					
Cleavage					
Streak					
Hardness					
Magnetic					
Effervescent					
Mineral type					

GROUNDRULES

GEOLOGY | AGE: 15 TO 18 | LENGTH: 2 HR | CURRICULUM: geologic structures, mapping

PLAYDOUGH TECTONICS

Description

Students will explore geologic structures, including flay-lying strata, anticlines, synclines and faults. They will gain an understanding of the order in which layers of rock are deposited. They will develop skills in drawing maps and cross-sections to scale.

VOCABULARY:

1. Strata
2. Canyon
3. Erosion
4. Fold
5. Syncline, anticline
6. Fault (normal, reverse, thrust, detachment, strike-slip)
7. Stratigraphic column
8. Cross section
9. Map scale
10. Graben and horst

MATERIALS:

- *Ground Rules* film
- Playdough (4 colors)
- Waxed paper
- Plastic knives
- Colored pencils (to match playdough colors)
- Rulers
- Protractors
- Rolling pins
- Stratigraphic Column sheet (provided)
- Optional: pictures of the Grand Canyon and folded/faulted rock structures

Introduction (Length: 15 minutes)

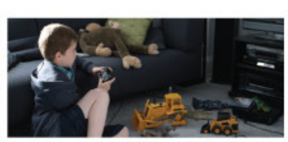
Ask the students if they have ever seen a rock cut (a place where the rock has been blasted or broken off so the vertical profile is exposed). What did they notice?

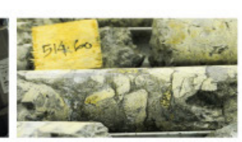
Discuss how layers of rock are deposited. The oldest layer is laid down first and the youngest layer is at the top. The layers are called strata. Mineral deposits may be found in one or more layers of rock. If there are layers of rock on top of the mineral deposit, these must be removed first before the minerals can be extracted. The overlying layers are sometimes called overburden. This material must be stockpiled while the mine is in operation. When mining is finished, this material is spread over the land again during the reclamation phase.

Watch Chapter 4 “Engineering Challenges” of the *Ground Rules* film. Focus on the open pit mining operation (Grasberg Mine) at the top of the mountain. Ask the students if they know how mountains are formed. Discuss the process of folding. How did the ore body get to the top of the mountain? Is the ore body likely younger or older than the rock at the base of the mountain?

How did the miners access the layers of mineral deposits? Briefly discuss the process of open pit mining.





Activity I (Length: 45 minutes)

The objective of this activity is to model a variety of geologic structures and prepare maps and cross-sections to scale.

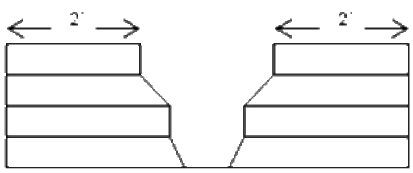
Flat-Lying Strata:

1. Lay a sheet of waxed paper (at least 5 inches by 10 inches) on the table.
2. Select one color of playdough. Remove approximately 2/3 of the playdough from the container and place it on the waxed paper. Roll it out into a rectangle that is approximately 1/4 inch thick and approximately 3 inches wide by 6 inches long.
3. Repeat the process with the other three colors of playdough.
4. Stack the layers neatly on top of each other and trim so the edges are even.
5. Turn the model so the 6 inch side is facing you. Keep the model in this orientation at all times.
6. Using colored pencils, fill in the squares on the Stratigraphic Column sheet. The colored boxes should match the colors in your strata model, with the oldest layer on the bottom and the youngest layer on the top.
7. Draw a cross-section diagram of the 6 inch side of your strata model. First draw a rectangle with the same dimensions as your model. Draw it at a scale of 2:1 (i.e., 2 inches on the paper equals 1 inch on the model). Use a ruler to accurately draw the depth of the layers. Label the oldest and youngest strata.

Erosion:

Simulate erosion of a canyon by cutting through the layers of playdough, as follows:

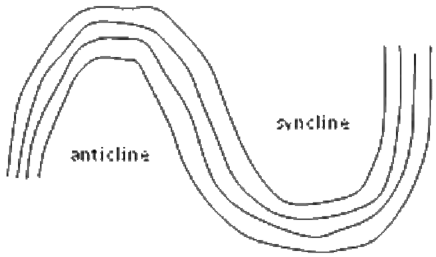
1. The canyon will be placed in the middle of the 6 inch side and will extend across the 3 inch width of the model.
2. Using a knife, slice through the top layer vertically at 2 inches from either end. Carefully remove the piece of playdough and put it aside (don't squish it).
3. Slice through the 2nd layer on a gentle slope towards the center. Carefully remove the piece of playdough and put it aside.
4. Slice through the 3rd layer vertically. Carefully remove the piece of playdough and put it aside.
5. Slice through the 4th layer on a gentle slope towards the center. Carefully remove the piece of playdough and put it aside.
6. Draw a map of the topography you see if you are looking down on the top of the model. Use a ruler to accurately measure the widths of each exposed layer on each side of the canyon you created. Label the youngest and oldest layers.
7. Draw a cross-section along the 6 inch side showing the canyon at a scale of 2:1. Label the youngest and oldest layers.



Anticlinal and Synclinal Folds:

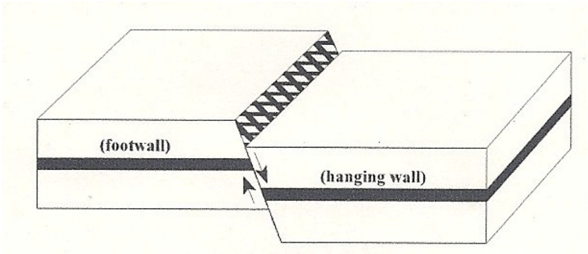
1. Fill in the canyon with the pieces of playdough that were removed in the erosion model, so it looks exactly as it did when it was first built.
2. Place your hands on the 3 inch ends of the model and press gently together horizontally. Let the waxed paper slide with the model. You should end up with an anticlinal and a synclinal fold. Hand-shape as necessary.

3. Stablize the folded layers by adding a bit of extra playdough under the bottom layer of the anticline.
4. Measure the interlimb angles of the anticline and syncline with a protractor. Describe the tightness of your fold as gentle (170º to 180º), open (170º to 90º), tight (90º to 10º) or isoclinal (10º to 0º).
5. Make a cross-section of your folded model at a scale of 2:1. Label the oldest and youngest layers. Label the anticline and the syncline. Draw dotted lines to mark the fold axes.
6. Measure the length of the model. Is it shorter or longer than the original model?



Normal Fault:

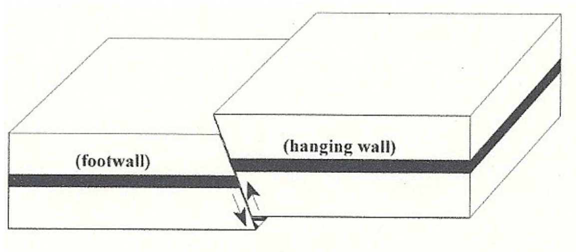
1. Return your model to the flay-lying strata position (i.e., undo the folding).
2. Using a knife, make a steep slanting cut from the top to the bottom through the playdough across the 3 inch width. Separate the two pieces.
3. Raise the left piece slightly and place some extra playdough underneath it to keep it raised. Push the right piece towards the left until they just barely touch. You have created a normal fault.
4. Draw a cross-section of the fault at a scale of 2:1. Label the oldest and youngest layers.
5. Measure the length of the model. Is it shorter or longer than the flat strata model?



Normal Fault

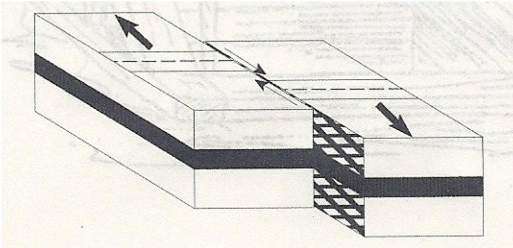
Reverse Fault:

1. Gently separate the two pieces of the normal fault.
2. Remove the extra playdough underneath the left piece and put it under the right piece, so that the right piece is higher than the left.
3. Push the left piece towards the right piece until they just barely touch. You have created a reverse fault.
4. Draw a cross-section of the fault at a scale of 2:1. Label the oldest and youngest layers.
5. Measure the length of the model. Is it shorter or longer than the normal fault model? Is it shorter or longer than the flat strata model?



Reverse Fault

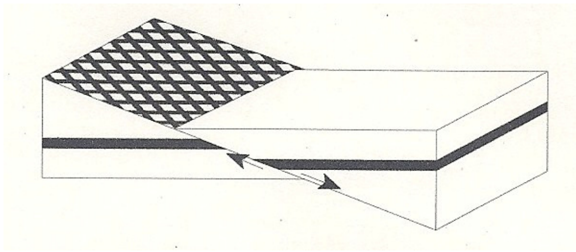
Strike-Slip Fault:
1. Gently re-join the fault halves to return to the flat strata model.
2. Scratch a "road" on the top of the model down the centre line parallel to the shortest side.
3. Using a knife, create a fault line through the model parallel to the longest side and slide the two halves horizontally.
4. Turn the model so that the fault line is parallel to the edge of the table where you are sitting.
5. Look at the half of the model that is furthest from you. Is it to the left or right of the portion nearest you? If the far side of the model is moved to the right, you have a right-lateral strike-slip fault. If the far side of the model is moved to the left, you have a left-lateral strike-slip fault.
6. Draw a cross-section of the fault at a scale of 2:1. Label the oldest and youngest layers and whether it is left-lateral or right-lateral.



Activity II (Length: 30 minutes)

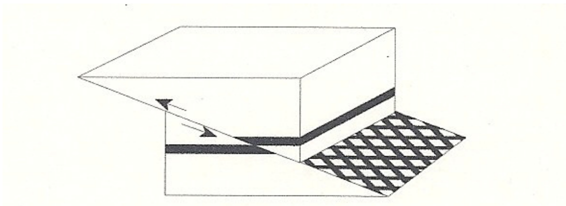
The objective of this activity is to use the knowledge gained in Activity I to build more complex geologic structures. Students should build a new flat-strata model with three layers to begin this activity. Do not show them the diagrams for 1 and 2 until they have completed the exercise.

1. Create a fault with a shallow or low-angle fault line. This is called a detachment fault. Pull the pieces apart until they are just touching. What do you notice about the length of this model compared to the normal fault model from Activity I?



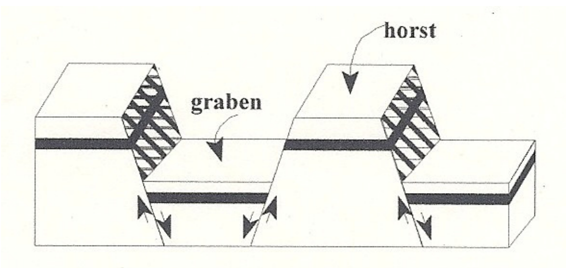
Detachment Fault

2. How can you take the two pieces of the fault model from #1 and create a structure where the bottom layer of rock is exposed? This is called a thrust fault. What do you notice about the length of this model compared to the reverse fault model from Activity I?



Thrust Fault

3. Try to make this model and explain how it would be created in nature.



4. Create a folded geological structure with an isoclinal tightness of 10º. What happens to the rock layers?

5. Create your own 4-layer model using a combination of folds and faults. Draw a cross-section diagram of the model at a scale of 1:1. Label the oldest and youngest layers. How many layers are exposed?

Discussion (Length: 30 minutes)

Activity I:
Which geologic structures result in an increased length compared to the flat strata model? Which result in a decreased length?

Discuss why a canyon might have “stepped” topography. Some rock layers may be more or less resistant to erosion, so not every rock layer will erode the same way as the layer above it. Why is a canyon V-shaped? The upper layers have had more time to erode, so the canyon is wider at the top than at the base. Show some pictures of the Grand Canyon to show the stepped topography.

Ask the students how they made their rock model fold. In nature, where do the compressive forces come from? Discuss how plate boundaries collide. Ask how many students were able to create a perfect symmetrical fold by pressure alone (without hand-shaping). Discuss the fact that folding rock layers in nature can be symmetrical or asymmetrical. In an asymmetrical fold, would the fold axis be vertical? No, it would be on an angle.

What would happen if you pushed with greater force from one direction than the other? You may end up with an overturned fold where the highest part of the fold leans over past the perpendicular direction. What would happen if you pushed the lower layers of rock with more force than the upper layers? The axial plane of a fold forms perpendicular to the greatest compressive stress. Show some pictures of folded rock. Folds are a deformational response to a compressive stress that is applied to a section of rock. These compressive stresses push on the rock. Because rock is solid, it cannot deform like a fluid by shortening and becoming thicker. Instead it folds.

Discuss the different types of faults and what happens to the rock layers in each. The San Andreas fault is a strike-slip fault that has displaced rocks hundreds of miles from their original location. As a result of the horizontal movement, rocks of different ages and composition can now be found side by side.

<u>Activity II</u>:
Define the terms horst and graben and how they apply to #3 of Activity II. Ask the students to describe in geologic terms what happens to the rock layers in this model. How many rock layers are exposed? Where are the oldest and youngest rock layers side by side?

Discuss what happened to the rock layers in #4 of Activity II. The rock layers would have folded on top of each other so the axis of the fold would have been nearly horizontal and the two limbs of the fold would be almost parallel to each other. If you took a core sample through the model, what would you see?

Ask the students to describe in geological terms what happened when they combined folding and faulting in their original model created in #5 of Activity II.

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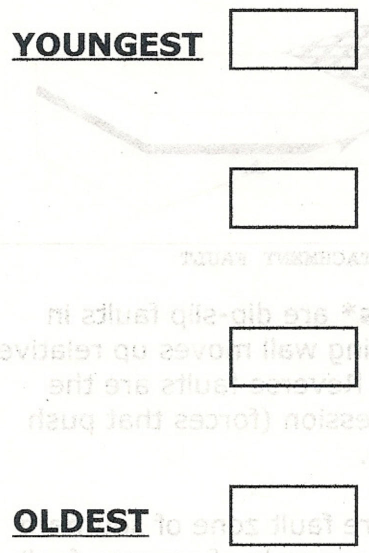
STRATIGRAPHIC COLUMN



GROUNDRULES

GEOLOGY	AGE: 15 TO 18	LENGTH: 1 HR	CURRICULUM: earth science, rock cycle/formation

ROCK CYCLE SIMULATION

Description

Students will explore the processes involved in the recycling of rocks.

VOCABULARY:

1. Sedimentary
2. Igneous
3. Metamorphic
4. Erosion
5. Deposition
6. Compaction
7. Cementation
8. Heat and pressure
9. Melting and cooling
10. Rock cycle

MATERIALS:

- One crayon per person (different colors)
- Coin
- Squares of aluminum foil
- Paper towels
- Candles and matches
- 2 ceramic tiles per group
- Tongs
- Data sheet (provided)

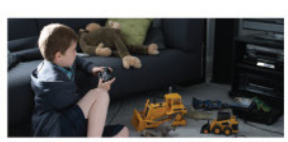
Introduction (Length: 15 minutes)

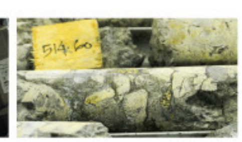
Introduce the concept of the rock cycle. Use the diagram below to explain the processes involved in the various stages of the rock cycle.

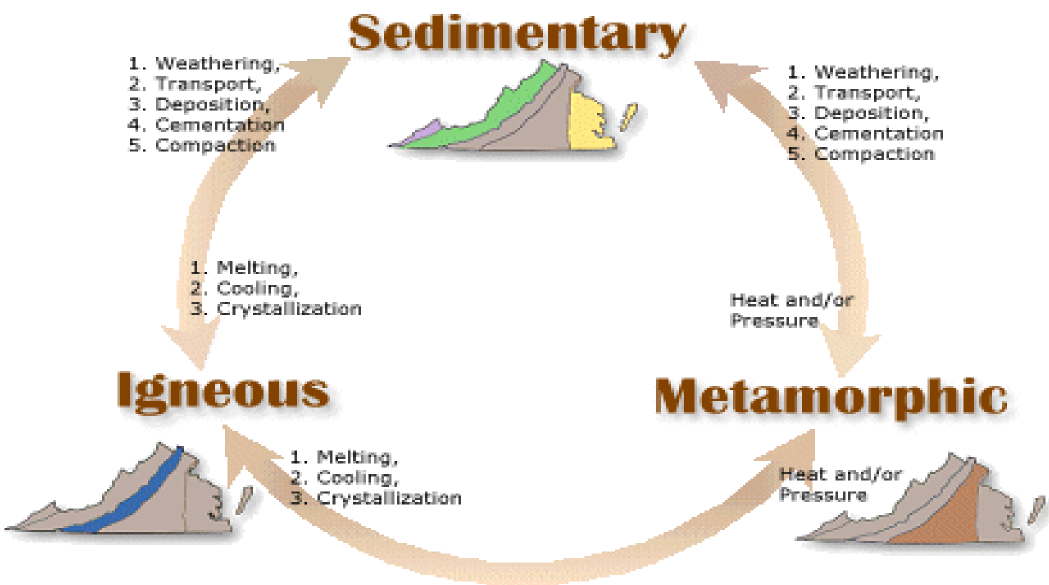
Rocks are formed very slowly as the Earth's crust goes through changes. Three types of rocks are formed: igneous, sedimentary and metamorphic. Many processes are continually at work changing and recreating rocks. These processes include erosion, deposition, cementation, compaction, heating and cooling and heat and pressure. Each type of rock can go through any of these processes. They are part of a larger process called the rock cycle.

Safety Precautions: Warn the students that they will be working with candle flames for this exercise, so they need to be careful not to get clothing or skin near the open flame. As soon as they are finished using the candle in the experiment, they should immediately extinguish it.







Activity (Length: 30 minutes)

The objective of this activity is to simulate the processes that occur in the rock cycle. The crayons represent rocks. Students should work in groups of 2, using two different coloured crayons.

<u>Part A: Making Sedimentary Rock</u>:

1. Simulate the process of erosion. Use a coin to shave a crayon into small pieces. Collect the shavings on a paper towel. Answer the questions for Part A-Erosion on the data sheet.
2. Simulate the process of deposition. Your actions will simulate the depositional force. Each lab partner should, in turn, pile their rock fragments in a neat pile in the center of the aluminum foil square, one color on top of the other. Answer the questions for Part A-Deposition on the data sheet.
3. Simulate the process of compaction. Carefully fold the aluminum foil over the loose layers of crayon shavings to make a packet. Place the foil packet in between two ceramic tiles and use all your strength to push down on the ceramic tiles to compact your crayon shavings. Carefully open the aluminum packet and observe your "sedimentary rocks". Answer the questions for Part A-Compaction on the data sheet.
4. Save a piece of your "sedimentary rock".

Part B: Making Metamorphic Rock:
1. Rewrap the aluminum foil packet.
2. Roll up your shirt sleeves. Carefully light your candle. Be careful not to get clothing or skin near the flame.
3. Grasp the foil packet with tongs. Carefully hold it an inch or two above a burning candle for short period of time to simulate the heating process. Do not fully melt the crayon, just soften it a bit. When finished, extinguish the candle.
4. Then quickly place the packet between the two ceramic tiles and compress. Use tongs to handle the packet at all times to avoid burns. After the foil packet has cooled, carefully open it up and observe your "metamorphic rocks".
5. Answer the questions on Part B of the data sheet.
6. Save a piece of your "metamorphic rock".

Part C: Making Igneous Rock:
1. Foil the 4 sides of the aluminum foil up to make a tray.
2. Roll up your shirt sleeves. Carefully light your candle. Be careful not to get clothing or skin near the flame.
7. Grasp the foil tray with tongs. Carefully hold it over a burning candle to fully melt the crayon. When finished, extinguish the candle.
3. Carefully place the tray on the table and allow it to cool.
4. This experiment can also be conducted using some of your left over crayon shavings or your piece of "sedimentary rock".
5. Answer the questions on Part C of the data sheet.

Use what you have learned in this simulation to answer the questions on Part D of the data sheet.

Discussion (Length: 15 minutes)

Discuss the answers to the questions on the data sheet.

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Data Sheet

Part A: Making Sedimentary Rock

1. Erosion Questions:

    a. What do the different colored crayons represent?

    b. Are the fragments all the same size or shape? Describe.

    c. Would this be true of rock fragments in nature?

    d. What are some of nature's tools to erode rocks?

2. Deposition Questions:

    a. Describe the shape and size of spaces between your rock (crayon) pieces. Are they large or small and irregular or regular shaped?

    b. How does nature move and lay down rock?

3. Compaction Questions:

    a. Do you see any layers? Are they thin or thick?

    b. Describe the compaction. Are they tightly or loosely compacted?

Part B: Making Metamorphic Rock

Heat and Pressure Questions:

a. Do you see any layers? Are they thin or thick?

b. Describe the compaction. Are they tightly or loosely compacted?

Part C: Making Igneous Rock

Melting and Cooling Questions:

a. Describe what the melted “rock” looked like (magma).

b. Describe the cooling process and the final appearance of the “igneous rock”.

Part D: Conclusions

Use your simulated “rocks” to help you describe how the following rock types are formed in nature:

a. Sedimentary Rocks:

b. Metamorphic Rocks:

c. Igneous Rocks: