GROUND**RULES**

GEOLOGY

Geology

AGES 11-13

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.

GROUNDRULES

GEOLOGY	AGE: 11 TO 13	LENGTH:45MIN	CURRICULUM: earth science, erosion process

EROSION DEMONSTRATION

Description

Students will learn how the process of erosion moves soil and rock and how this process can expose valuable minerals in the underlying deposits, such as gold or diamonds.

VOCABULARY:

1. Erosion
2. Gravity

MATERIALS:

- *Ground Rules* film
- Long tray (cookie sheet, garden flat)
- Large plastic bucket
- Two cups of fine dry soil and sand mixture
- Half cup of pebbles (variety of shapes – flat, rounded, pointed)
- A few shiny pennies
- Water in a pitcher or bottle

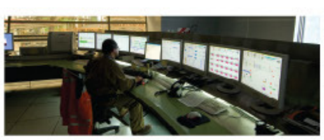
Introduction (Length: 15 minutes)

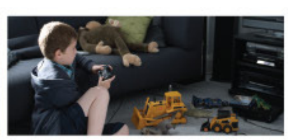
Watch Chapter 1 “Exploration” of the *Ground Rules* film. Focus on the section where the miners are panning sediments in a stream. Ask the students why the geologists are looking for metals in a stream bed. Many valuable metals, like gold, were first discovered this way. Why? The answer is erosion.

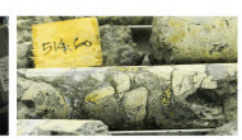
Ask the students what erosion means. Erosion is the process by which the surface of the earth (soil, rocks, and minerals) is worn away by the movement of gravity, wind, glaciers and water. Due to erosion, the surface of the Earth is constantly changing. Materials are moved around, exposing previously buried materials. Sometimes these materials are valuable minerals like gold or diamonds.

Explain that the students are going to build a model of a stream bed that contains some valuable gold (represented by the pennies). They will simulate the process of erosion by adding flowing water to the stream bed.

Have students make hypotheses about what will happen during the demonstration. Which materials will travel down the tray into the bucket? Why? Which materials will stay behind? Will the size and shape of the pebbles affect how they react to the movement of the water?

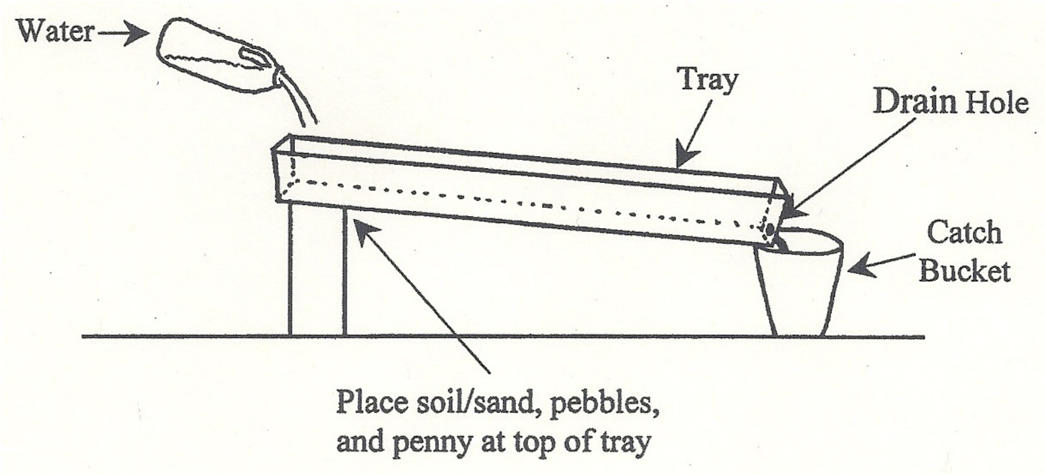







Activity (Length: 15 minutes)

1. Make sure the tray is watertight. Make a large hole at one end so water and associated materials will be able to flow freely through the hole.
2. Set the tray at approximately a 20º angle.
3. Place the bucket under the drain hole to catch the run-off.
4. Take a look at the different sizes and shapes of the pebbles. Their size and shape will have an effect on how they react to the erosion.
5. Mix the pebbles and pennies into the soil/sand mixture.
6. Spread all of the mixture on the raised end of the tray. This simulates a streambed.
7. Slowly pour the water over the mixture and observe what happens. A slow, steady pour is best to simulate water flowing through a stream.



Discussion (Length: 15 minutes)

Review the hypotheses the students made before the demonstration and discuss the observations made by the students during the experiment.

The water moved from high elevation to low elevation due to gravity. As the water moved, it transported sand and pebbles. These collided against each other. In real life, the sand and pebbles would collide against each other as well as against the bedrock. This causes erosion, affecting the pebbles, rocks, sediment, and the bedrock.

The lighter materials are picked up and transported by water. The copper pennies are heavier and are not easily transported by water. Gold and diamonds are also much heavier minerals. Therefore they are not easily transported by the flow of water. When sediment is washed away, the heavy minerals are revealed. This is how the first discovery of gold was made.

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.

GROUNDRULES

GEOLOGY	AGE: 11TO13	LENGTH: 2 HR	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

MATERIALS:

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

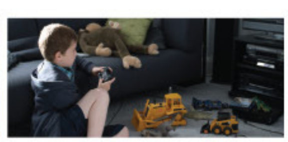
Introduction (Length: 15 minutes)

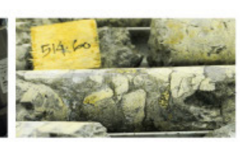
Display a variety of different types of sedimentary rocks (and one or two igneous or metamorphic rocks) at the front of the class. Ask the students what kind of rocks these are? Are they all the same kind? Ask them to find the one or two rocks that are different than the rest. Discuss the differences 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: 15 minutes)

The objective of this activity is to learn about the classification system for sedimentary rocks.

1. Divide the class into teams of 3 or 4 students.
2. Give each team several samples of different types of sedimentary rocks.
3. Ask each team to sort the sedimentary rocks into groups based on visual observation and handling of the rocks only. They can group them any way they think makes sense. Ask each group to explain how they sorted the rocks into groups. What was the basis of classification? (e.g., colour, size, composition, weight).
4. Next, ask each group to sort the sedimentary rocks by grain size. They can examine the rock types with a magnifying glass to do this.

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.

Activity II:
Explain that geologists classify sedimentary rocks according to grain size. The following classifications are typically used: shale, sandstone, conglomerate, gravel, coal, limestone, till and topsoil.

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.

GROUNDRULES

GEOLOGY	AGE:11TO13	LENGTH: 1.5HR	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. Hardness
6. Streak
7. Magnetism

MATERIALS:

- *Ground Rules* film
- Mineral identification key (provided)
- Mineral Identification Table (provided)
- 5 numbered mineral samples (good quality)
- A few different minerals to use for demonstrations
- Hand lens or magnifying glass
- Streak plates
- Copper pennies
- Steel files or nails
- Bar magnets
- Glass microscope slides

Introduction (Length: 20 minutes)

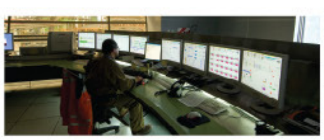
Ask students what a mineral is. Minerals are solid, inorganic substances that occur naturally and have specific structures and chemical compositions. Minerals are present in rocks and can be extracted by mining in order to make all of the things we use in our everyday lives.

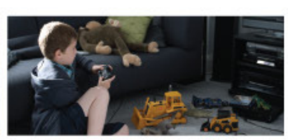
Watch Chapter 3 “Mining and the Modern World” of the *Ground Rules* film. Discuss the importance of minerals in our everyday lives.

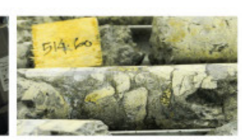
Ask students if they know how to recognize a specific mineral from another. You can tell the differences between minerals by looking for certain properties. Because each mineral is unique both chemically and structurally, each has its own set of physical, optical and structural properties, which aid in its identification. Chemistry refers to the basic building blocks or elements that make up the mineral. 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 properties of minerals that can be tested to identify a mineral. These are color, luster, streak, hardness and magnetism.

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. Non-metallic minerals can be dull or shiny, but they don't have a metallic look. Explain that non-metallic minerals can be further described by the type of surface they have, but that is beyond the scope of this activity. Use a couple of samples to show the difference between metallic and non-metallic luster (don't use the samples that will be used in the activity).

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. Demonstrate how to streak a mineral and have the class tell you what color they observe.

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

Demonstrate how to determine the hardness of a mineral sample.

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

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

Activity (Length: 50 minutes)

The objective of this activity is to identify 5 mineral samples by testing five common properties.

Preparation:

1. Choose 5 high quality mineral specimens that can easily be identified by color, luster, steak, hardness and magnetism. Some good mineral samples to use are: magnetite, hematite, talc (soapstone), quartz, chalcopyrite, pyrite, feldspar.
2. Use the mineral identification key provided to make your own mineral identification key that contains only the 5 minerals they will be evaluating.

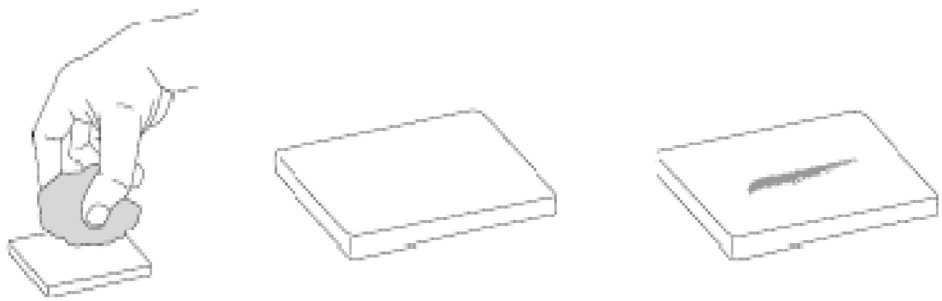
3. Prepare five mineral identification stations. Each station should have a numbered mineral, a Mineral Identification Table (for recording answers), a streak plate, a hand lens, hardness tools and a magnet.
4. Divide the class into five groups. One group should be at each station to start.
5. Each group will have 10 minutes to determine the mineral properties for the sample at the first station. 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. Decide whether your mineral has a metallic or non-metallic luster. Does it sparkle when light reflects off of its surface (like aluminum foil)? 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.

3. 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.



4. 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 hardness tool. 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 (identified in the introduction) 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 microscope slide with your mineral. If the mineral scratches the glass, 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.

5. 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".

6. Move to the next station and repeat steps 1-5. Continue until all five minerals have been tested.

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

Discussion (Length: 20 minutes)

Review the answers with the class and see how many specimens each group determined correctly. If there were some specimens 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 specimen? Which property was the least helpful? Which mineral was the easiest to identify?

Watch Chapter 3 of the *Ground Rules* film again. Use the film to make a list of the items that are made of the minerals you identified in this activity.

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Mineral Identification Key (Some Common Minerals)

Mineral	Color	Luster	Streak	Hardness	Magnetic
Bauxite	red, brown, yellow	non-metallic	light brown, white	1-3	no
Calcite	varies(1)	non-metallic	white	2.5-3	no
Chalcopyrite	yellow-gold	metallic	greenish-black	4	no
Dolomite	varies(2)	non-metallic	white	3.5-4	no
Feldspar	varies(3)	non-metallic	white	6	no
Fluorite	varies(4)	non-metallic	white	4	no
Garnet	white to dark gray, red	non-metallic	none	6.5	no
Hematite	red-brown, gray, black	metallic	reddish-brown	5-6(6)	no
Hornblende	dark green, black	non-metallic	none	5-6	no
Magnetite	black	metallic	black	6	yes
Pyrite	yellow-gold	metallic	greenish-black	6	no
Pyrrhotite	yellow-gold	metallic	dark gray-black	3.5-4.5	yes
Quartz	varies(5)	non-metallic	white	7	no
Talc	gray, white	non-metallic	white	1	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

Mineral Identification Table

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

GEOLOGY	AGE: 11 TO 13	LENGTH:1.75HR	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)
7. Stratigraphic column
8. Cross section

MATERIALS:

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

Introduction (Length: 15 minutes)

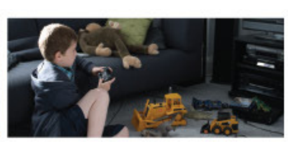
Ask the students if they have ever seen a rock cut (a place where the rock has been blasted or broken off so the vertical profile is exposed). What did they notice?

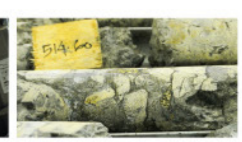
Discuss how layers of rock are deposited. The oldest layer is laid down first and the youngest layer is at the top. The layers are called strata. Mineral deposits may be found in one or more layers of rock. If there are layers of rock on top of the mineral deposit, these must be removed first before 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.



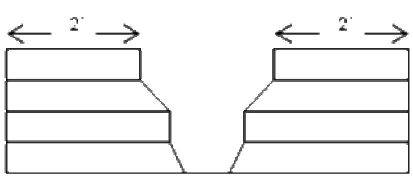


Activity (Length: 60 minutes)

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

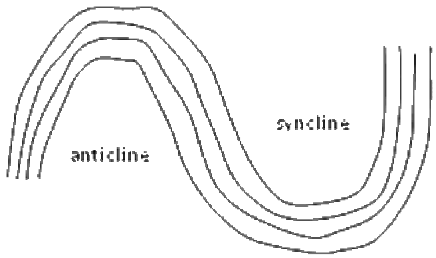
Flat-Lying Strata:
1. Lay a sheet of waxed paper (at least 5 inches by 10 inches) on the table.
2. Select one color of playdough. Remove approximately 2/3 of the playdough from the container and place it on the waxed paper. Roll it out into a rectangle that is approximately 1/4 inch thick and approximately 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 1:1 (i.e., 1 inch 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. Label the youngest and oldest layers.

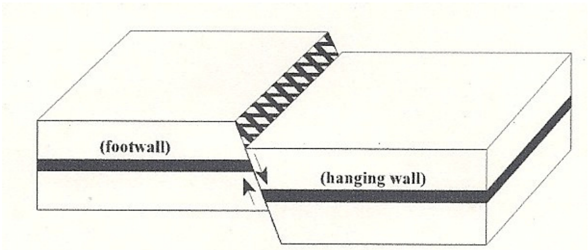


Anticlinal and Synclinal Folds:
1. Fill in the canyon with the pieces of playdough that were removed in the erosion model, so it looks exactly as it did when it was first built.
2. Place your hands on the 3 inch ends of the model and press gently together horizontally. Let the waxed paper slide with 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. Make a cross-section of your folded model at a scale of 1:1. Label the oldest and youngest layers. Label the anticline and the syncline.
5. Measure the length of the model. Is it shorter or longer than the original model?

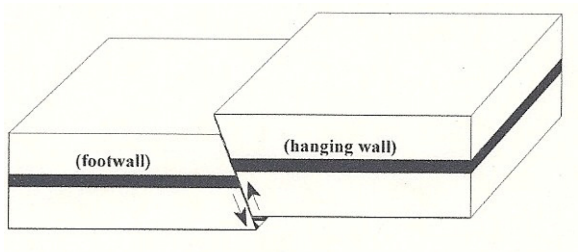


Normal Fault:
1. Return your model to the flay-lying strata position (i.e., undo the folding).
2. Using a knife, make a slanting cut from the top to the bottom through the playdough across the 3 inch width. Separate the two pieces.
3. Raise the left piece slightly and place some extra playdough underneath 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 1:1. 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.
6. Draw a cross-section of the fault at a scale of 1:1. Label the oldest and youngest layers.
4. 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

Discussion (Length: 30 minutes)

Review each of the modeled geologic structures. Ask some of the students to show their cross section diagrams to the class.

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 fold by pressure alone (without hand-shaping). Discuss the fact that folding rock layers in nature are rarely perfect. What would happen if you pushed with greater force from one direction than the other or pushed the lower layers of rock with more force than the upper layers? Show some pictures of folded rock.

Ask some of the students to share their observations about model length for the fold and fault activities. Which geologic structures result in an increased length compared to the flat strata model? Which result in a decreased length?

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.

STRATIGRAPHIC COLUMN

YOUNGEST

OLDEST

GROUNDRULES

GEOLOGY | AGE: 11 TO 13 | LENGTH: 1 HR | CURRICULUM: earth science, sedimentary rock

SEDIMENTARY ROCK FORMATION

Description

Students will learn that sedimentary rocks are formed out of material which has been deposited by water.

VOCABULARY:

1. Sedimentary
2. Igneous
3. Metamorphic
4. Mineral deposits
5. Magma
6. Sediments
7. Topsoil

MATERIALS:

- *Ground Rules* film
- Samples of sedimentary rock (limestone, sandstone, conglomerate, gypsum)
- Recycled quart jar (pickle jar or mason jar)
- 4 tablespoons of coarse sand
- 4 tablespoons of fine sand
- 4 tablespoons of fine pebbles
- Water

Introduction (Length: 15 minutes)

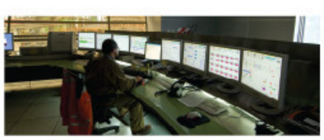
Watch Chapter 1 “Exploration” of the *Ground Rules* film. Focus on the section where geologists are panning for minerals in the New Guinea wetland.

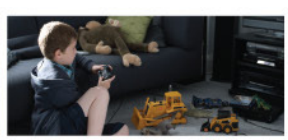
Discuss how rocks are classified into three main groups: igneous, metamorphic and sedimentary rocks. Mineral deposits are also classified into these three types.

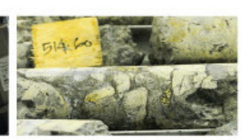
Igneous rocks form when volcanoes erupt. Boiling magma comes up to the earth’s surface, cools and turns into solid rock. Magma cools very slowly but in doing so, it also gets very hard.

What word does metamorphic sound like? It sounds like metamorphosis, which means a change in shape or form. Metamorphic rock is formed when the earth’s crust moves and causes rock to squeeze together so hard that intense heat is produced. This heat causes the rock to change its shape and structure. Metamorphic rock is the least common of all three types of mineral deposits.

The most common type of mineral deposit is sedimentary rock deposits. Sedimentary mineral deposits are created by erosion. When mountains are first formed, they are jagged and tall, resembling the Rocky Mountains on the West coast of Canada and the United States. Over time these mountains become less jagged and more rounded. Erosion is the process of rock and sand being worn away by rain and ice. The little bits of rock that crumble their way down the mountain are called sediments. These sediments usually end up in streams and rivers that flow down the mountain. Once the water slows down, the sediments settle to the bottom of the water source. Over many years, sediments create layers of different rock fragments mixed with the mud and sandy bottom of the water source. This is how sedimentary rocks are formed. The layers of rock that are on the top of a deposit are younger than those found underneath.





Pass around some samples of different types of sedimentary rocks.

Activity (Length: 15 minutes + 10 minutes follow-up)

The objective of this activity is to show how sedimentary rocks are formed.

1. Put the sand, fine soil, and fine pebbles into the quart jar.
2. Fill the jar with water, put the top on, and shake it up.
3. Set the jar down and watch what happens. The pebbles go to the bottom immediately. The sand falls to form a layer. Then sand and larger pieces of soil fall on top of that. Deposited at the top is a layer of the finer soil.
4. Leave the jar in a place where it won't be disturbed for several days. During this time, most of the materials will settle and the water will become almost clear.
5. Have the students make final observations after all the materials have settled.

Discussion (Length: 20 minutes)

Discuss what happens when mineral particles are carried by water to lakes or oceans. As the water slows down, the material settles, with heavier pieces being deposited first. Lighter pieces stay on top and layers are formed. Limestone and shale are minerals that typically form this way. This is also why miners often temporarily remove topsoil to get to a mineral deposit buried underneath.

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