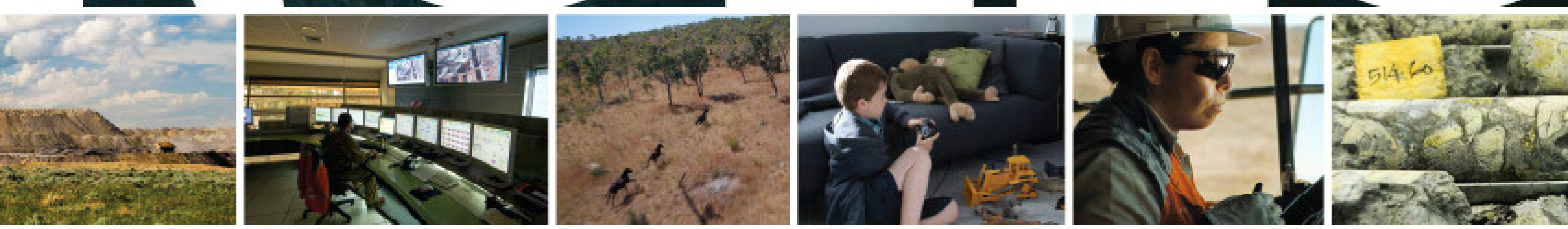
Mining Right for a Sustainable Future

GROUND RULES



Lesson Plans

FOR USE WITH STUDENTS AGES 11-18

CATERPILLAR®

TABLE OF CONTENTS

Introduction

Geology

Lesson Plans for Ages 11 to 13

Erosion Demonstration
Making Sandstone, Conglomerate and Limestone
Mineral Identification
Playdough Tectonics
Sedimentary Rock Formation

Lesson Plans for Ages 13 to 15

Crystal Formation from Minerals
Making Sandstone, Conglomerate and Limestone
Mineral Identification
Playdough Tectonics
Sedimentary Rock Formation

Lesson Plans for Ages 15 to 18

Crystal Formation from Minerals
Making Sandstone, Conglomerate and Limestone
Mineral Identification
Playdough Tectonics
Rock Cycle Simulation

Mining

Lesson Plans for Ages 11 to 13

Building an Open Pit Mine
Building an Underground Mine
Environmental Monitoring – pH and Temperature
Mining Careers
Mine Safety and Hazard Identification

Lesson Plans for Ages 13 to 15

Building an Open Pit Mine
Cross-Section Model of an Underground Mine
Environmental Monitoring – pH, Temperature, Conductivity, Dissolved Oxygen
Mining Careers
Mine Safety and Mining Accidents

Lesson Plans for Ages 15 to 18

Building an Open Pit Mine
Building a 3-Dimensional Underground Mine
Designing a Mine
Environmental Monitoring – pH, Temperature, Conductivity, Dissolved Oxygen
Mining Careers

Mining Processes

Lesson Plans for Ages 11 to 13

Mass, Volume, Density and Specific Gravity
Mining Monopoly
Orebody Mystery
Reclaiming a Mine Site
The Wheelbarrow Advantage

Lesson Plans for Ages 13 to 15

Mass, Volume, Density and Specific Gravity
Mining Process Game
Orebody Mystery
Reclaiming a Mine Site
The Wheelbarrow Advantage

Lesson Plans for Ages 15 to 18

Develop a Closure and Reclamation Plan
Mining Process Game
Orebody Mystery
Reclaiming a Mine Site
What are the Ground Rules?

Ore Processing

Lesson Plans for Ages 11 to 13

Electroplating Pennies
Extracting Copper from Sulfide Ores
Floating Coal
Leaching to Separate Metals from Ore
Magnetic Separation

Lesson Plans for Ages 13 to 15

Electrowinning Experiment
Extracting Copper from Sulfide Ores
Floating Coal
Leaching to Separate Metals from Ore
Magnetic Separation

Lesson Plans for Ages 15 to 18

Electrowinning Experiment
Extracting Copper from Sulfide Ores
Leaching to Separate Metals from Ore
Making Steel and Steel Alloys
Mining Equipment

Minerals and Everyday Life

Lesson Plans for Ages 11 to 13

Making a Flashlight
Magnetic Cereal
Mineral Content Matching Game
Toothpaste Experiment
Which Materials in a Pencil are Mined/Grown?

Lesson Plans for Ages 13 to 15

Consumption of Mineral Resources
Minerals in my House
Minerals at School
Minerals in Toothpaste
What Parts of a Computer are Mined?

Lesson Plans for Ages 15 to 18

Consumption of Mineral Resources
Lifecycle of Coal
Minerals in my House
Mineral Design
What Parts of a Computer are Mined?

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 1: 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.

Theme 2: Mining

This theme teaches students about open pit and underground mining, including safety and environmental considerations. It also introduces students to a wide range of mining careers. Students will build models of open pit and underground mines, with increasing complexity in each age category. The 15 to 18 year-old students will build on these concepts to design a mine based on a cross-sectional diagram of a hypothetical ore body. Younger students will explore the potential safety hazards at mine sites, learn how to identify safety hazards, and learn about methods used by mining companies to keep their workers safe. All age groups will learn about environmental monitoring of water bodies at mine sites and will test up to four different water quality parameters through age-appropriate field and classroom activities.

Theme 3: Mining Processes

This theme covers the processes involved in mining, from exploration and site development to reclamation. The core lesson plan is a game in which students explore the various phases involved in the development of a mine and the economic aspects of these phases. Through this game, students will gain an understanding of the decision-making processes involved in determining whether an ore body can be profitably mined. The game increases in complexity with age category. The orebody mystery is an exploration game in which students collect playdough core samples, analyze them for mineral content, and map the extent of an ore body. Younger students investigate the concept of mechanical advantage by looking at simple mining tools, as well as the concepts of mass, volume, density and specific gravity in relation to gold panning. In the reclamation activity, students will experiment with growing plants on reclaimed landscapes. The 15 to 18 year-old students will develop a closure and reclamation plan for a hypothetical mine site and make decisions with respect to engineering challenges, environmental impacts and social implications involved in developing a mine.

Theme 4: Ore Processing

This theme explores the different methods that can be used to extract and purify valuable minerals from mined ore. Students will conduct a series of experiments to learn about the processes of crushing, milling, extraction, leaching, flotation and purification. Younger students will also use magnetism to separate minerals, and will use froth flotation to separate coal from sand. The 15 to 18 year-old students will study the process of making steel, as well as the types of heavy equipment used to haul ore to processing facilities.

Theme 5: Minerals and Everyday Life

This theme shows students how important minerals are in their everyday lives. It also examines some of the properties of minerals that make them useful. Younger students will investigate the minerals present in food, toothpaste and different objects in their home and school. They will identify the resources used to make a pencil, whether these resources are mined or grown, and how many countries it takes to make a pencil. They will explore the properties of copper by building a flashlight with copper wire. Older students will research the minerals and metals that are used to make various components of a computer. They will determine why these mined resources are useful to computers and extrapolate their findings to other electronic devices. They will keep a diary of items and associated minerals they use in a day to determine their daily “mineral consumption”. The 15 to 18 year-old students will explore the benefits and impacts of coal. They will research the new technologies of methane capture, liquid gasification and carbon capture/sequestration, which are designed to reduce greenhouse gases generated by coal combustion.

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

Geology

AGES 11-13

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)

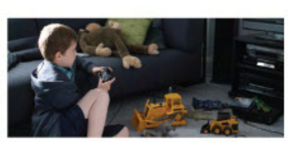
Watch Chapter 1 “Exploration” of the *Ground Rules* film. Focus on the section where the miners are panning sediments in a stream. Ask the students why the geologists are looking for metals in a stream bed. Many valuable metals, like gold, were first discovered this way. Why? The answer is erosion.

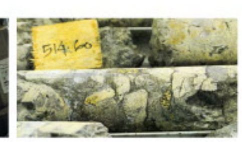
Ask the students what erosion means. Erosion is the process by which the surface of the earth (soil, rocks, and minerals) is worn away by the movement of gravity, wind, glaciers and water. Due to erosion, the surface of the Earth is constantly changing. Materials are moved around, exposing previously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

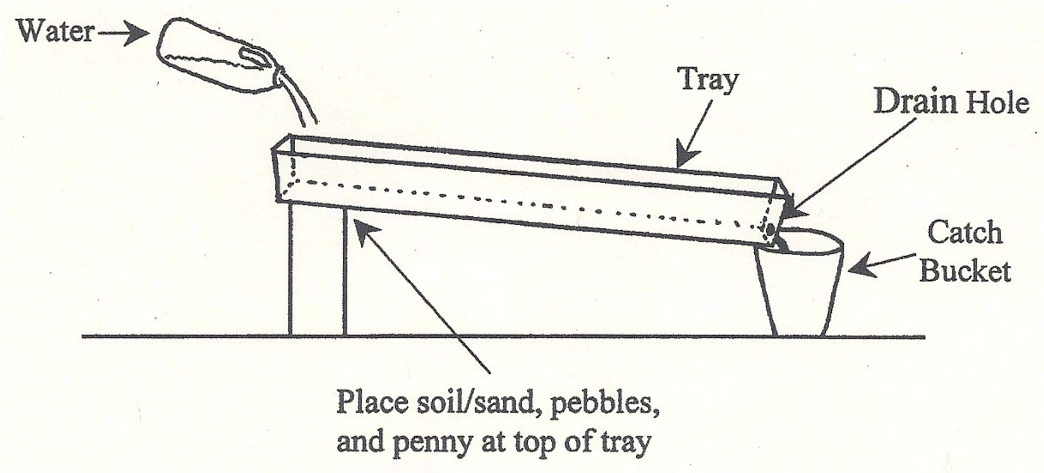




Activity (Length: 15 minutes)

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.

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:

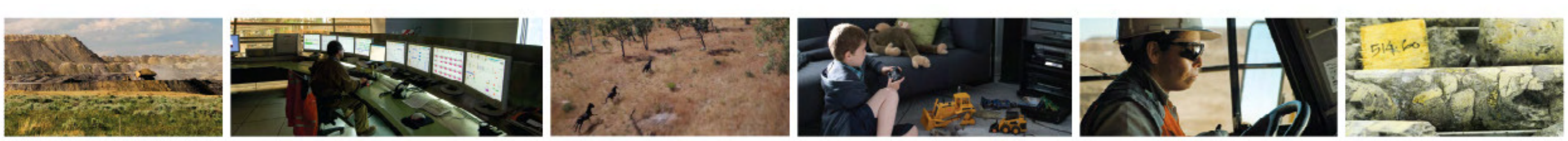
- Dry sand
- Cementing solution (2 parts water, 1 part Epsom salt)
- Small paper cups and 2 shoeboxes
- Mixing sticks
- Garbage bags and sandwich bags
- Dry cement
- Water
- Small rocks and pieces of shells
- Dry plaster
- Magnifying glasses
- Samples of different types of sedimentary rocks and a few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

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)

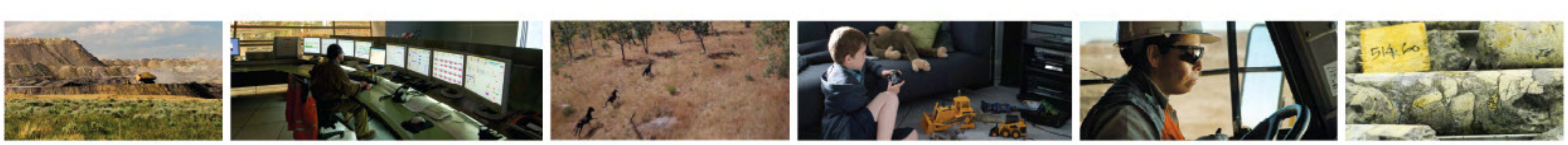
Ask students what a mineral is. Minerals are solid, inorganic substances that occur naturally and have specific structures and chemical compositions. Minerals are present in rocks and can be extracted by mining in order to make all of the things we use in our everyday lives.

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.

<u>Preparation</u>:

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.

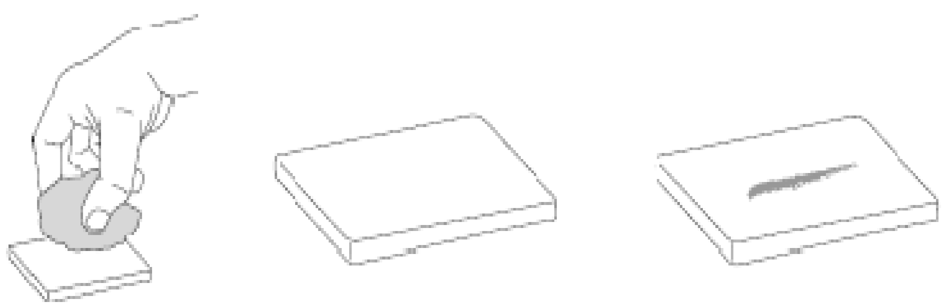
3. Prepare five mineral identification stations. Each station should have a numbered mineral, a Mineral Identification Table (for recording answers), a streak plate, a hand lens, hardness tools and a magnet.
4. Divide the class into five groups. One group should be at each station to start.
5. Each group 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. <u>Penny test</u>: 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. <u>Steel file/nail test</u>: 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. <u>Glass test</u>: 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. <u>Magnetism</u>: 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.

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.

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)

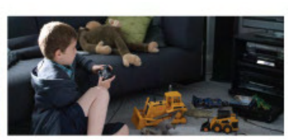
Ask the students if they have ever seen a rock cut (a place where the rock has been blasted or broken off so the vertical profile is exposed). What did they notice?

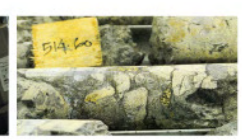
Discuss how layers of rock are deposited. The oldest layer is laid down first and the youngest layer is at the top. The layers are called strata. Mineral deposits may be found in one or more layers of rock. If there are layers of rock on top of the mineral deposit, these must be removed first before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



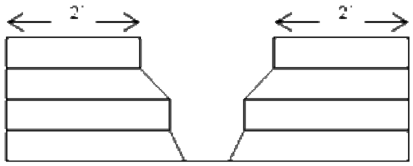


Activity (Length: 60 minutes)

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

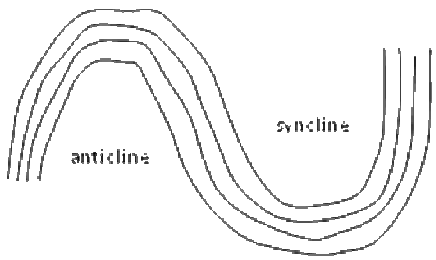
Flat-Lying Strata:
1. Lay a sheet of waxed paper (at least 5 inches by 10 inches) on the table.
2. Select one color of playdough. Remove approximately 2/3 of the playdough from the container and place it on the waxed paper. Roll it out into a rectangle that is approximately 1/4 inch thick and approximately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

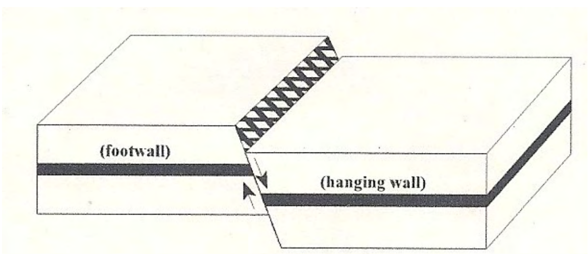


Anticlinal and Synclinal Folds:
1. Fill in the canyon with the pieces of playdough that were removed in the erosion model, so it looks exactly as it did when it was first built.
2. Place your hands on the 3 inch ends of the model and press gently together horizontally. Let the waxed paper slide with 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?

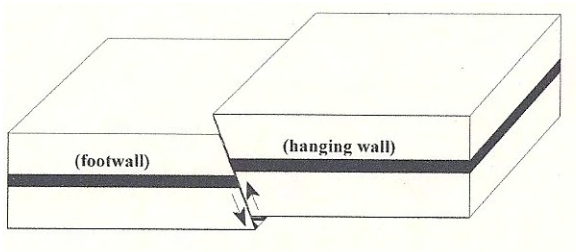


Normal Fault:
1. Return your model to the flay-lying strata position (i.e., undo the folding).
2. Using a knife, make a slanting cut from the top to the bottom through the playdough across the 3 inch width. Separate the two pieces.
3. Raise the left piece slightly and place some extra playdough underneath 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?

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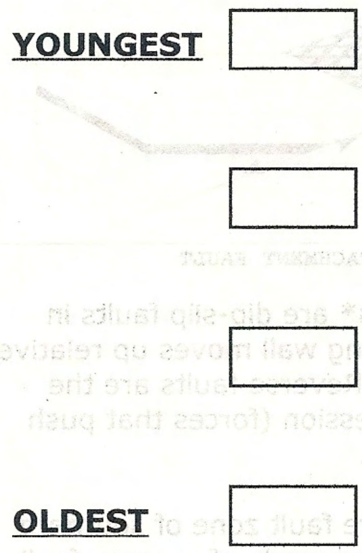
STRATIGRAPHIC COLUMN



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.

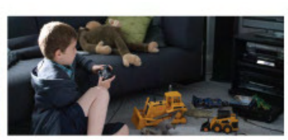
Discuss how rocks are classified into three main groups: igneous, metamorphic and sedimentary rocks. Mineral deposits are also classified into these three types.

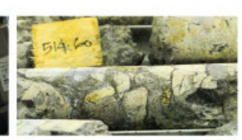
Igneous rocks form when volcanoes erupt. Boiling magma comes up to the earth's surface, cools and turns into solid rock. Magma cools very slowly but in doing so, it also gets very hard.

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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GROUND**RULES**

GEOLOGY

Geology
AGES 13-15

GROUNDRULES

GEOLOGY | AGE: 13 TO 15 | LENGTH: 1 HR | CURRICULUM: earth science, chemistry, graphing

CRYSTAL FORMATION FROM MINERALS

Description

Students will observe the process of crystal formation, measure crystal growth and learn to distinguish between stalactites and stalagmites.

VOCABULARY:

1. Crystal
2. Atom
3. Molecule
4. Solution
5. Ion
6. Reaction
7. Precipitate
8. Dependant variable
9. Independent variable
10. Bar 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

Introduction (Length: 15 minutes)

Ask the students if they know what stalactites and stalagmites are. How are they formed? Where do you find them?

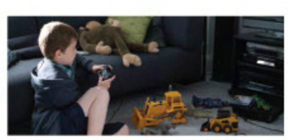
Stalactites form on the roof of a cave and grow downwards, while stalagmites form on the floor and grow upwards.

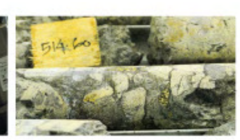
Stalactites and stalagmites are usually found in limestone caves and are composed mainly of calcite, a common mineral found in sedimentary rocks. The key ingredient to making stalactites and stalagmites is water. When rainwater trickles through cracks in the rocks, it picks up carbon dioxide and minerals 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 that then grow upwards.

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.

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 (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 bar graph on graph paper showing the rate of crystal growth over time. Use three colors of bars to represent the three colors of crystals.

Discussion (Length: 15 minutes)

Discuss the results of the experiment. Look at the bar graphs. Which crystals grew longer? Which crystals formed faster? Which type of crystal was more abundant?

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.

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GEOLOGY | AGE: 13 TO 15 | 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:

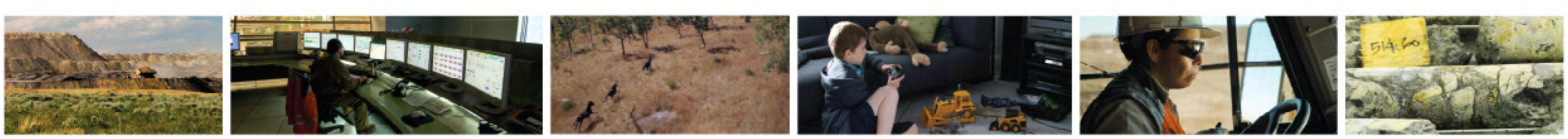
- Dry sand, dry cement and dry plaster
- Cementing solution (2 parts water, 1 part Epsom salt)
- Small paper cups and 2 shoeboxes
- Mixing sticks
- Garbage bags and sandwich bags
- Water
- Small rocks and pieces of shells
- Magnifying glasses
- Samples of different types of sedimentary rocks and a few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

MATERIAL:

- *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
- Glass microscope slides
- Diluted hydrochloric acid/vinegar & eyedropper
- 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.

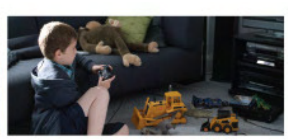
Watch Chapter 3 “Mining and the Modern World” of the *Ground Rules* film. Discuss the importance of minerals in our everyday lives.

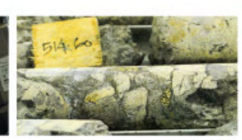
Ask students if they know how to recognize a specific mineral from another. You can tell the differences between minerals by looking for certain properties. Because each mineral is unique both chemically and structurally, each has its own set of physical, optical and structural properties, which aid in its identification. Chemistry refers to the basic building blocks 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 (Length: 50 minutes)

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

Preparation:

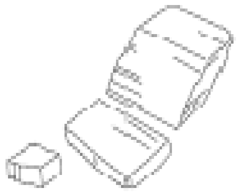
1. Choose 5 high quality mineral samples that can easily be identified by color, luster, cleavage, steak, hardness and magnetism. Some good mineral samples to use are: magnetite, hematite, talc (soapstone), quartz, chalcopyrite, pyrite, feldspar.
2. Prepare five mineral identification stations. Each 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 goggles and gloves.
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 (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. 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.

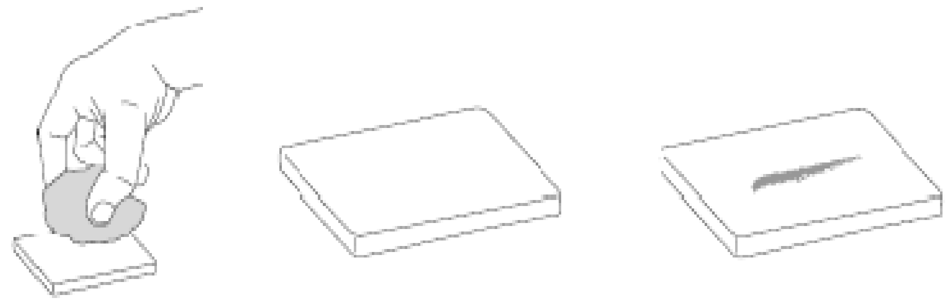
3. Cleavage: Look at the broken surfaces of your mineral with a hand lens. How does your mineral look on the surfaces where it has been broken? Did the mineral break along flat surfaces? If yes, then your mineral has cleavage. If no, then your mineral does not have cleavage. Write "yes" or "no" in the cleavage box on the Mineral Identification Table. If the mineral does not have cleavage, it will fracture into jagged pieces as shown below.



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 1-7. 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.

Discussion (Length: 20 minutes)

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 together as a class.

Which properties were the most helpful for identifying each mineral sample? 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	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: 13 TO 15 | 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, 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)

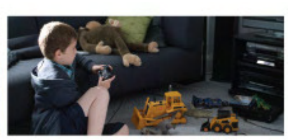
Ask the students if they have ever seen a rock cut (a place where the rock has been blasted or broken off so the vertical profile is exposed). What did they notice?

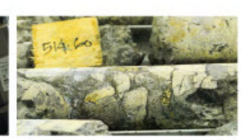
Discuss how layers of rock are deposited. The oldest layer is laid down first and the youngest layer is at the top. The layers are called strata. Mineral deposits may be found in one or more layers of rock. If there are layers of rock on top of the mineral deposit, these must be removed first before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



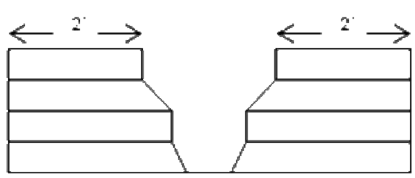





Activity I (Length: 45 minutes)
The objective of this activity is to model a variety of geologic structures and prepare maps and cross-sections to scale.

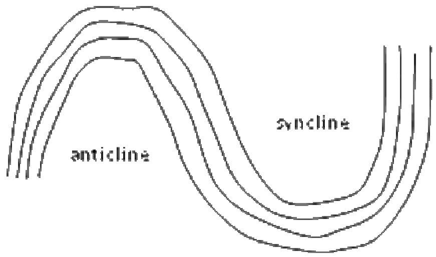
Flat-Lying Strata:
1. Lay a sheet of waxed paper (at least 5 inches by 10 inches) on the table.
2. Select one color of playdough. Remove approximately 2/3 of the playdough from the container and place it on the waxed paper. Roll it out into a rectangle that is approximately 1/4 inch thick and approximately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



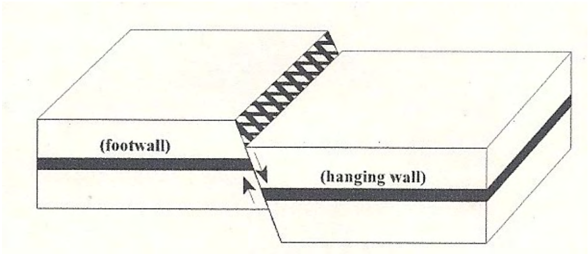
Anticlinal and Synclinal Folds:
1. Fill in the canyon with the pieces of playdough that were removed in the erosion model, so it looks exactly as it did when it was first built.
2. Place your hands on the 3 inch ends of the model and press gently together horizontally. Let the waxed paper slide with 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 1:1. 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?



<u>Normal Fault</u>:

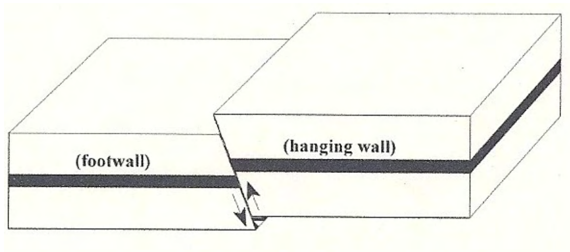
1. Return your model to the flay-lying strata position (i.e., undo the folding).
2. Using a knife, make a steep slanting cut from the top to the bottom through the playdough across the 3 inch width. Separate the two pieces.
3. Raise the left piece slightly and place some extra playdough underneath it 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 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

<u>Reverse Fault</u>:

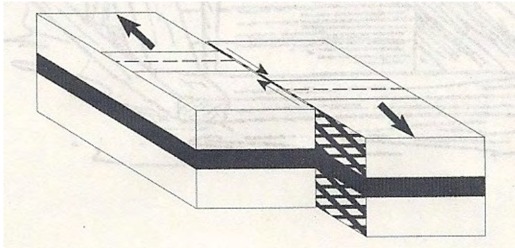
1. Gently separate the two pieces of the normal fault.
2. Remove the extra playdough underneath the left piece and put it under the right piece, so that the right piece is higher than the left.
3. Push the left piece towards the right piece until they just barely touch. You have created a reverse fault.
4. Draw a cross-section of the fault at a scale of 1:1. 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:

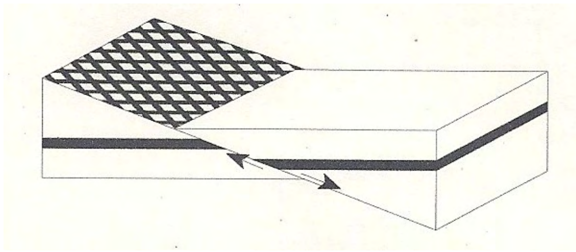
1. Gently re-join the fault halves to return to the flat strata model.
2. Scratch a “road” on the top of the model down the centre line parallel to the shortest side.
3. Using a knife, create a fault line through the model parallel to the longest side and slide the two halves horizontally.
4. Turn the 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 1:1. Label the oldest and youngest layers and whether it is left-lateral or right-lateral.



Activity II (Length: 15 minutes)

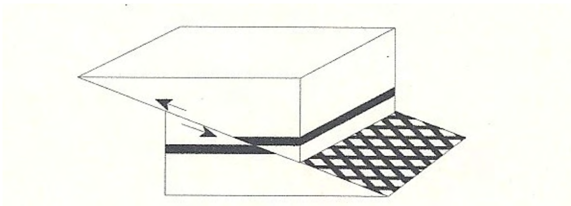
The objective of this activity is to use the knowledge gained in Activity I to build more complex geologic structures. Students should build a new flat-strata model with three layers to begin this activity. Do not show them the diagrams for 1 and 2 until they have completed the exercise.

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?



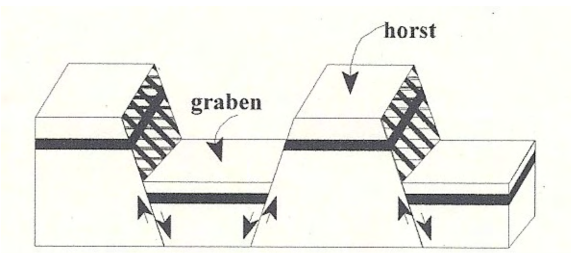
Detachment Fault

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.



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.

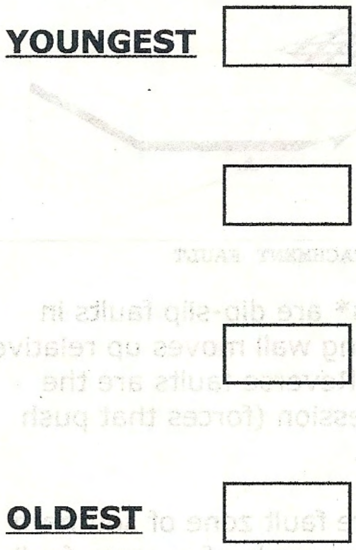
Ask the students how they made their rock model fold. In nature, where do the compressive forces come from? Discuss how plate boundaries collide. Ask how many students were able to create a perfect symmetrical fold by pressure alone (without hand-shaping). Discuss the fact that folding rock layers in 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.

Activity II:
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?

STRATIGRAPHIC COLUMN



GEOLOGY | AGE: 13 TO 15 | 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.

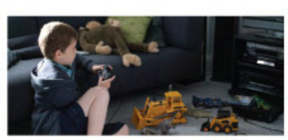
Discuss how rocks are classified into three main groups: igneous, metamorphic and sedimentary rocks. Mineral deposits are also classified into these three types.

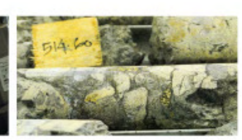
Igneous rocks form when volcanoes erupt. Boiling magma comes up to the earth’s surface, cools and turns into solid rock. Magma cools very slowly but in doing so, it also gets very hard.

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.

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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GROUND**RULES**

GEOLOGY

Geology

AGES 15-18

GEOLOGY | AGE: 15 TO 18 | LENGTH: 2 HR | CURRICULUM: earth science, chemistry, graphing

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)

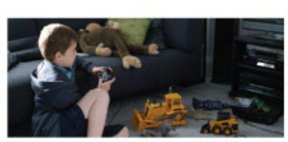
Ask the students what a crystal is. In crystals of any kind, atoms or molecules join together in a pattern that repeats itself over and over to create a specific shape. The crystals grow by repeating the exact same pattern continuously.

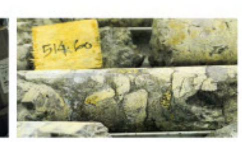
Ask the students if they know what stalactites and stalagmites are. Where do you find them? They are typically found in limestone caves. Stalactites form on the roof of a cave and grow downwards, while stalagmites form on the floor and grow upwards.

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.

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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

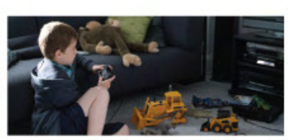
Introduction (Length: 15 minutes)

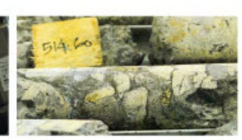
Display a variety of different types of sedimentary rocks (and one or two igneous or metamorphic rocks) at the front of the class. Ask the students what kind of rocks these are? Are they all the same kind? Ask them to find the one or two rocks that are different than the rest. Discuss the differences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

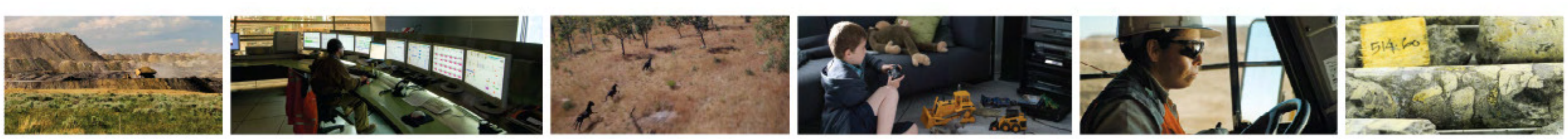
Ask students what a mineral is. Minerals are solid, inorganic substances that occur naturally and have specific structures and chemical compositions. Minerals are present in rocks and can be extracted by mining in order to make all of the things we use in our everyday lives.

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)

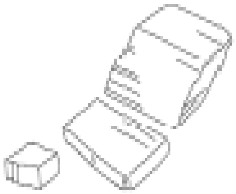
The objective of this activity is to identify 5 mineral samples by testing various physical properties.

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.

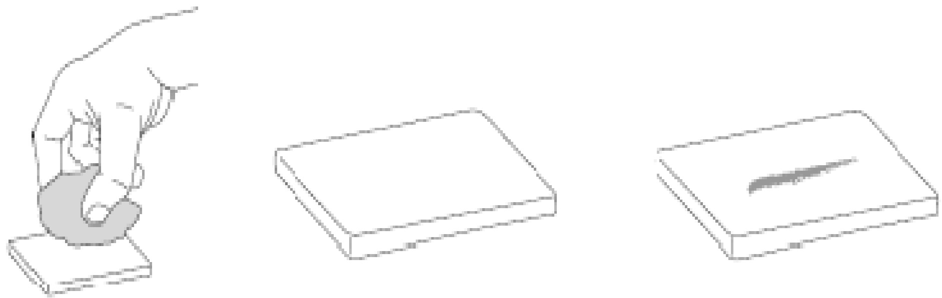
3. Cleavage: Look at the broken surfaces of your mineral with a hand lens. How does your mineral look on the surfaces where it has been broken? Did the mineral break along flat surfaces? If yes, then your mineral has cleavage. If no, then your mineral does not have cleavage. Write "yes" or "no" in the 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)

<u>Activity I</u>:
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?

<u>Activity II</u>:
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)

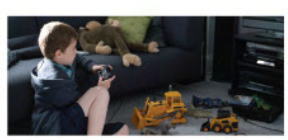
Ask the students if they have ever seen a rock cut (a place where the rock has been blasted or broken off so the vertical profile is exposed). What did they notice?

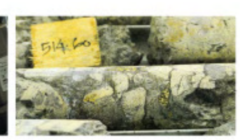
Discuss how layers of rock are deposited. The oldest layer is laid down first and the youngest layer is at the top. The layers are called strata. Mineral deposits may be found in one or more layers of rock. If there are layers of rock on top of the mineral deposit, these must be removed first before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

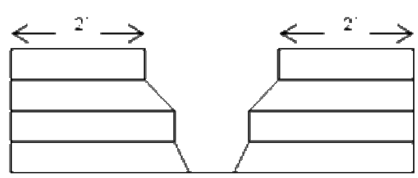
Flat-Lying Strata:

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:

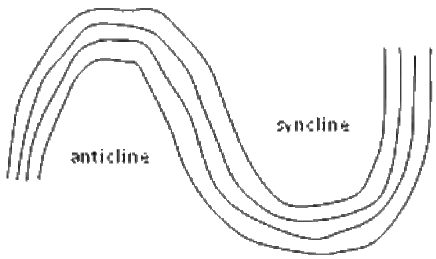
1. The canyon will be placed in the middle of the 6 inch side and will extend across the 3 inch width of the model.
2. Using a knife, slice through the top layer vertically at 2 inches from either end. Carefully remove the piece of playdough and put it aside (don't squish it).
3. Slice through the 2nd 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:

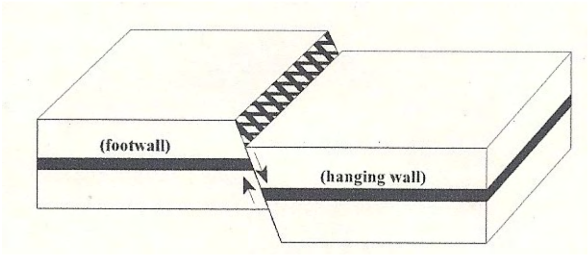
1. Fill in the canyon with the pieces of playdough that were removed in the erosion model, so it looks exactly as it did when it was first built.
2. Place your hands on the 3 inch ends of the model and press gently together horizontally. Let the waxed paper slide with the model. You should end up with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

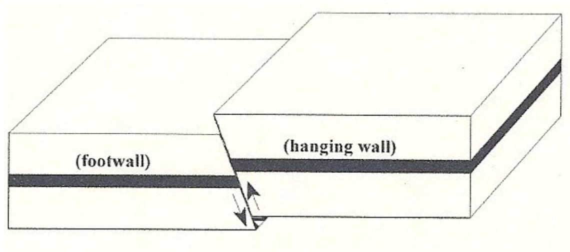
1. Return your model to the flay-lying strata position (i.e., undo the folding).
2. Using a knife, make a steep slanting cut from the top to the bottom through the playdough across the 3 inch width. Separate the two pieces.
3. Raise the left piece slightly and place some extra playdough underneath it 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

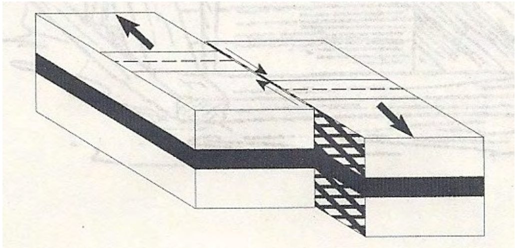
Reverse Fault:

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

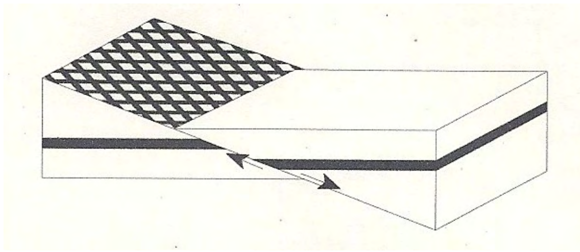
Strike-Slip Fault:
1. Gently re-join the fault halves to return to the flat strata model.
2. Scratch a "road" on the top of the model down the centre line parallel to the shortest side.
3. Using a knife, create a fault line through the model parallel to the longest side and slide the two halves horizontally.
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)

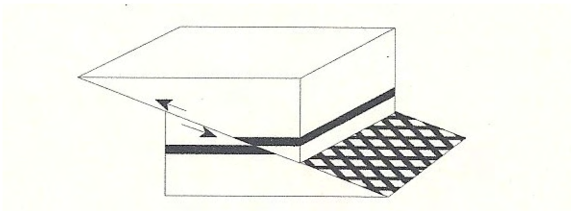
The objective of this activity is to use the knowledge gained in Activity I to build more complex geologic structures. Students should build a new flat-strata model with three layers to begin this activity. Do not show them the diagrams for 1 and 2 until they have completed the exercise.

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?



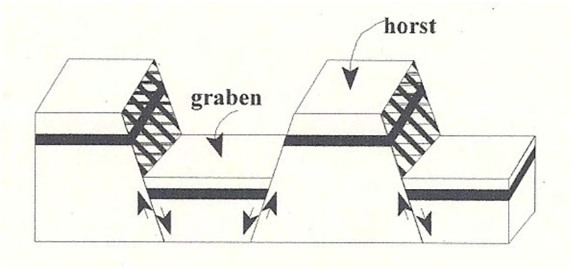
Detachment Fault

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.

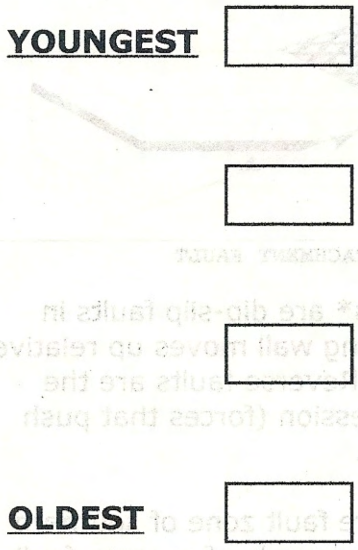
Discuss the different types of faults and what happens to the rock layers in each. The San Andreas fault is a strike-slip fault that has displaced rocks hundreds of miles from their original location. As a result of the horizontal movement, rocks of different ages and composition can now be found side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

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)

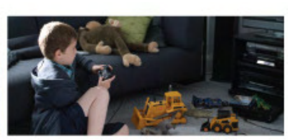
Introduction (Length: 15 minutes)

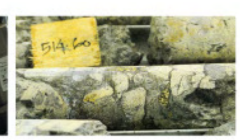
Introduce the concept of the rock cycle. Use the diagram below to explain the processes involved in the various stages of the rock cycle.

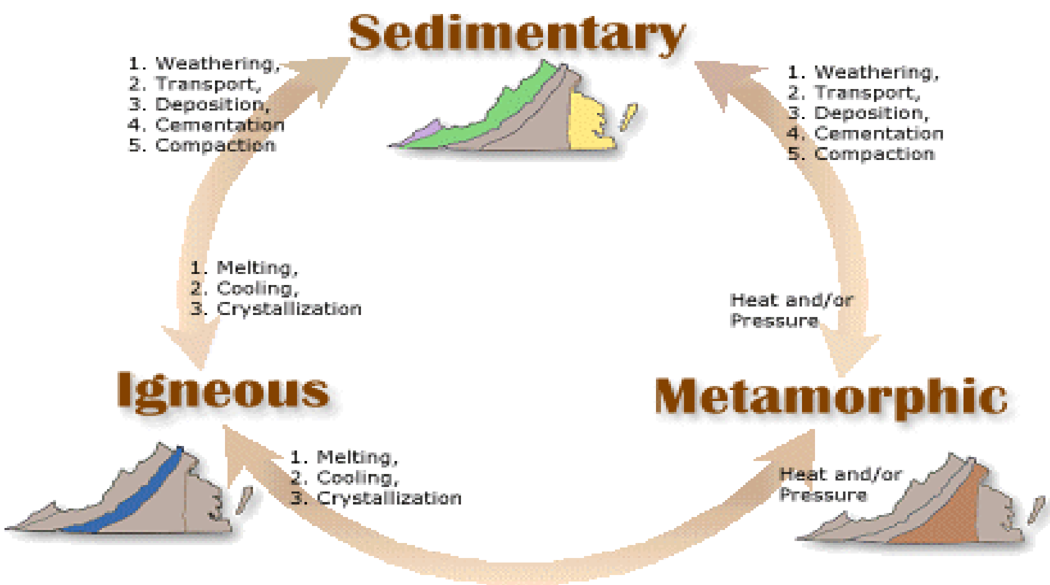
Rocks are formed very slowly as the Earth's crust goes through changes. Three types of rocks are formed: igneous, sedimentary and metamorphic. Many processes are continually at work changing and recreating rocks. These processes include erosion, deposition, cementation, compaction, heating and cooling 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.

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.

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:

GROUNDRULES

MINING

Mining
AGES 11-13

MINING	AGE: 11 TO 13	LENGTH:1.5 HR	CURRICULUM: earth science, mining

BUILDING AN OPEN PIT MINE

Description

Students will build an open-pit mine and learn how ore is extracted from shallow ore bodies.

VOCABULARY:

1. Open pit
2. Overburden
3. Benches
4. Slope
5. Truck route

MATERIALS:

- *Ground Rules* film
- Mixture of sand and pebbles
- Water
- Carving tools (scoops, spoons, spatulas, plastic knives)
- Ruler
- Large plastic or wooden boxes
- Small toy dump trucks and scoops
- Large buckets/pails (ore buckets)

Introduction (Length: 30 minutes)

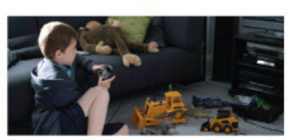
Watch Chapter 2 “Modern Mining” and Chapter 4 “Engineering Challenges” of the *Ground Rules* film. Chapter 2 shows an open pit copper mine in Chile, while Chapter 4 shows an open pit gold and copper mine in Papua Indonesia. Pause the film to look at the structure of the open pit mines featured in each of these film chapters.

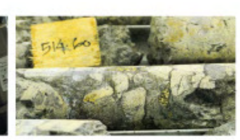
Under what circumstances are open pits used? Ask the students what they notice about the structure of these open pit mines. Discuss the function of the benches or stepped sides of the pit. Discuss the width to height ratio of the open pit structures. What would happen if the pit was deep and narrow? Explain that an open pit mine has to be wider than its depth to maintain a safe structure.

What equipment is used in the open pit mine? How does the size of this equipment compare to the equipment used in an underground mine?

What was the greatest challenge in building the open pit mine in Papua Indonesia? The ore body is at the top of a mountain. In some ways, this poses as great or an even greater challenge than sinking shafts to mine underground. Discuss the similarities and differences of open pit mining at the top of a mountain versus mining a deposit that is deep below the earth’s surface (e.g., tramway to reach the top versus cage and shaft to reach the bottom; hauling the ore down the mountain versus hauling the ore up to the surface; building a road to the top versus sinking a shaft and digging tunnels underground). The blasting and loading processes to remove the ore are similar.





Activity (Length: 45 minutes)

The objective of this activity is to build a model of an open pit mine and learn how ore is extracted from shallow ore bodies.

1. Divide the class into groups of 3 or 4 students. Each group will build a model of an open pit mine. The goal is to build an open pit mine as deep as possible within the constraints of the box width.
2. Fill a large box approximately half full with the sand-pebble mixture. Add some water and mix it in to make a mixture that can be molded. Spread the mixture flat and pack it down.
3. Using a variety of tools, begin to carve out the open pit mine. Create the benches on the sides. Use a ruler to measure and build benches of uniform height and width. Remember to make some wider benches to be used for truck routes.
4. Discard the material dug out from the mine into the ore buckets.
5. Dig as deep into the mine as you can before the sides get too steep.
6. Use the wider benches to create a truck route from the top of the mine to the bottom. Use the toy trucks to determine the sizes of the truck routes (must be wide enough for two truck lanes).

Discussion (Length: 15 minutes)

What were the challenges involved in creating the open pit mines? How much time did it take to dig out the mine, build the benches and truck routes? Discuss how much time it would have taken you to do this using the toy trucks and shovels (i.e., when the scale of the equipment used is proportional to the mine). Discuss the importance of large equipment to increase the efficiency of the open-pit mining process. What are the challenges of operating such large equipment?

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

MINING | AGE: 11 TO 13 | LENGTH:1.5HR | CURRICULUM: earth science, mining

BUILDING AN UNDERGROUND MINE

Description

Students will build a 3-dimensional model of an underground mine using toilet rolls. They will learn how ore is extracted from deep ore deposits.

VOCABULARY:

1. Mine shaft
2. Headframe
3. Cage
4. Skip
5. Drift
6. Ventilation shaft
7. Stope
8. Ore body
9. Ore pass

MATERIALS:

- *Ground Rules* film
- Toilet rolls and paper towel rolls
- Scissors
- Tape
- String
- Bar magnet
- Pencils and paper
- Cardboard
- Markers
- Small metal objects (coins, washers, bolts)
- Straws, sticks or long-handled narrow spoons
- Miscellaneous craft items

Introduction (Length: 30 minutes)

Watch Chapter 5 “Going Underground” of the *Ground Rules* film. Pause on the animated picture of the underground mine. Ask the students what the vertical and horizontal tunnels are called. What is one way (shown in the film) that underground mining has been made safer in recent years? (remote controlled vehicles)

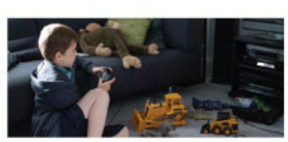
Under what circumstances are underground mines used?

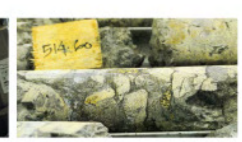
Describe the process of underground mining. What are the components of an underground mine? What is the purpose of the headframe? Describe the cables and winch system that are located in the headframe to lower the cage of miners into the mine and haul out the ore in the skip. What is the purpose of the ventilation shaft? Explain that the ventilation shaft can also be used as an emergency escape route.

How do workers access the ore body from the shaft? Discuss the process of tunneling into the rock to create drifts to access the ore body. What is a stope? Discuss the process of blasting to loosen the ore.

How is the ore removed from the mine? Discuss the use of ore passes to deliver the ore from various drifts to the bottom of the mine where it may be crushed and raised to the surface in the skip.





If there are local underground mines in your area, use these as examples to illustrate the concept of underground mining.

Activity (Length: 45 minutes)

The objective of this activity is to build a model of an underground mine, showing all of the features that are present in underground mines.

1. Divide the class into groups of 3 to 4 students. Each group will create a unique model of an underground mine.
2. Begin by sketching a design on paper. Include the main shaft, a ventilation shaft, at least 2 drifts, 1 stope per drift, and an ore pass that connects the drifts.
3. Using the toilet and paper towel rolls, tape, and scissors, create a 3-dimensional structure of the sketched underground mine. Create the mine shaft, ventilation shaft, drifts and the ore pass. Cut holes into the tubes when you need to attach pieces vertically to the middle of tubes (e.g., for the ore pass).
4. Create a stope on each drift by cutting a 1 inch (2.5 cm) diameter hole in the top of one section of the drift tube.
5. Using cardboard and various craft materials, design a headframe with sides but no bottom or top. Attach it to the top of the mine shaft with tape.
6. Attach string to the bar magnet (this will simulate the skip). Cut the string long enough to reach from the top of the mine shaft to the bottom. Test it out by lowering it through the top of the headframe into the mine shaft and pulling it out.
7. Stand the model up vertically in a physical support or have one student hold it firmly.
8. Test out the model by adding some small metal objects (ore) to one of the stopes in one of the drifts (through the opening on the top of the toilet tube). Use sticks, straws or long handled spoons to push or pull the ore to the ore pass opening on that drift. Allow the ore to fall to the bottom of the ore pass and into the bottom of the main shaft.
9. Lower the magnet on a string (to simulate the lowering of the skip), pick up the ore at the bottom of the mine shaft and bring it to the surface.

Discussion (Length: 15 minutes)

What were the challenges involved in building the underground mine models? When each model was tested, were there any areas where the ore was blocked from passing through? Discuss the challenges involved in building a real underground mine. How is the ore moved from the stopes to the ore pass in a real underground mine?

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MINING | AGE: 11 TO 13 | LENGTH: 2 HR | CURRICULUM: earth science, chemistry, environment

ENVIRONMENTAL MONITORING - pH AND TEMPERATURE

Description

Students will learn about environmental monitoring of water bodies at mine sites. They will collect water samples from a local water body and test them for pH and temperature.

VOCABULARY:

1. Acidic
2. Basic
3. Neutral
4. pH
5. Temperature
6. Water quality
7. Samples
8. Acid rain
9. Sulfur dioxide

MATERIALS:

- *Ground Rules* film
- Litmus paper or universal indicator and color chart
- Waterproof thermometer
- Lemon juice and eye dropper
- Milk of magnesia or toothpaste
- Distilled water
- Tap water
- Rain water (optional)
- Hip or chest waders, rubber boots, life jackets
- Clipboard and notepaper
- Small plastic bottles with lids
- Data sheet (provided)

Introduction (Length: 30 minutes)

Watch Chapter 7 “Mining and the Environment” of the *Ground Rules* film. This chapter shows an example of how potential environmental impacts of a mine site were minimized at the McArthur River Mine in Australia.

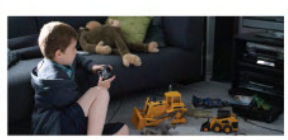
Ask the students to name some of the possible environmental impacts of a mine (for example: water quality, air quality, land disturbance, removal of vegetation/habitat).

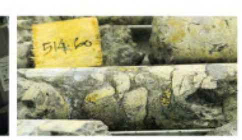
What major environmental challenge did Xstrata have to overcome before it could open the McArthur River Mine? (re-routing of the river). Discuss the challenges associated with rerouting the river (maintaining biodiversity, maintaining natural features of a river channel, water quality).

What does an environmental technician do at a mine site? Explain that in this activity, the students will be the “environmental technicians” of a hypothetical mine site. They will collect water samples and test them for pH and temperature.

Why is water temperature important to measure? Abnormally warm water may reduce the ability of the water to hold dissolved oxygen which is necessary for aquatic life. Dissolved oxygen can also be measured directly with a special probe.





Introduce the pH scale and explain what is meant by the terms acidic, basic and neutral. The pH scale ranges from 0 to 14, with 7 being neutral. Numbers below 7 are acidic, while numbers above 7 are basic. The pH scale is logarithmic, so each number represents a 10-fold change. For example, a change from pH 7 to pH 6 means the acidity of the solution has increased by 10 times.

Explain that water quality monitoring at a mine site is conducted in order to evaluate possible changes that have occurred as a result of mining activities. Explain that each water body has a unique natural chemistry and there is not a standard pH value that is considered "normal" for all water bodies. Therefore, before the mine site is developed, water quality in each local water body that may be impacted by the mine is tested, so that there is a record of what is "normal" for each water body. This is often called baseline water quality. Then, after the mine is in operation, the water can be tested on a regular basis and compared to the baseline values to see if there has been a change in water quality. A change in pH may indicate a change in the chemistry of the water body.

The pH of normal rainwater is slightly acidic (pH 5.6) due to the presence of carbon dioxide gas. The pH of many water bodies ranges from 6 to 8. Fish and aquatic organisms begin to be affected when the pH drops below 5.

pH Scale:

0 1 2 3 4 5 6 $\boxed{7}$ 8 9 10 11 12 13 14

$\longleftarrow$ increasingly acidic — neutral — increasingly basic $\longrightarrow$

Activity (Length: 30 minutes field location;30 minutes classroom)

The objective of this activity is to collect and test water samples from a local water body for pH and temperature.

1. Optional: Collect some rainwater in a small plastic bottle prior to the activity. Secure the lid tightly and keep in a cool place until the day of the activity.
2. Visit a local water body (lake or stream). For safety reasons, avoid fast-flowing rivers. Bring small plastic bottles, a thermometer, life jackets, notepaper and clipboards and waders/rubber boots.
3. For safety reasons, wear a life jacket at all times while water sampling.
4. Hold the thermometer in the water for a minute. Record the temperature on the clipboard notepaper. Test the water in a few places and record the temperature each time.
5. Wade into the water and collect a few samples of water in plastic bottles. Be careful to collect only water in the bottle (no sediment or plant material). Secure lids tightly.
6. Return to the classroom.
7. Transfer the temperature readings to Section A of the data sheet and answer the second question.
8. Test the pH of the water samples with litmus paper or universal indicator. Fill out Section B, Question 1 on the data sheet.

9. Test the pH of lemon juice, milk of magnesia/toothpaste, distilled water and tap water (optional: also test pH of rainwater). Record the pH measurements. Answer Questions 2 to 5 in Section B on the data sheet.
10. Pour ½ cup of distilled water into a clean sample bottle. Add a few drops of lemon juice. Test the pH. Continue adding a few drops at a time and testing again. Each time, record the total number of drops added and the pH measurement in Section C on the data sheet until you reach a pH of 5. Answer the remaining questions on the data sheet.

Discussion (Length: 30 minutes)

Review the answers to the questions on the data sheet. How might a mine site affect the temperature of a nearby water body? This could occur if the mine discharges warm water into a local water body. Explain that modern mines have a responsibility to protect the environment surrounding the mine. If they discharge water to the environment, they must ensure that the quality and temperature of the water is suitable to protect aquatic organisms and their habitat.

How might emissions from a mine site affect the pH of a nearby water body? Explain that a chemical called sulfur dioxide may be released to the air during the smelting process. In the atmosphere, sulfur dioxide combines with water and produces acid rain. When acid rain falls onto a water body, it can make the water acidic over time. Explain how modern mines install pollution control equipment to minimize the amount of sulfur dioxide released.

Other parameters that might be measured to monitor water quality in a water body near a mine site may include: dissolved oxygen, conductivity and turbidity. In addition, samples may be collected a few times per year and sent to a laboratory for chemical analysis.

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.

Environmental Monitoring Data Sheet

A) Water Temperature

1. Record the water temperatures measured in the waterbody. What is the average temperature? Did the temperature vary depending on where the sample was taken?

2. Would fish and other aquatic organisms be able to live in water that is this temperature?

B) pH

1. Record the pH measurements for the water samples collected from the water body.

2. Record the pH measurement for the lemon juice. Is this acidic, basic or neutral? Write lemon juice beside the correct pH value on the pH scale.

3. Record the pH measurement for the milk of magnesia/toothpaste. Is this acidic, basic or neutral? Write milk of magnesia/toothpaste beside the correct pH value on the pH scale.

4. Record the pH measurement for the tap water. Is this acidic, basic or neutral? Write tap water beside the correct pH value on the pH scale.

5. Record the pH measurement for the distilled water. Is this acidic, basic or neutral? Write tap water beside the correct pH value on the pH scale.

6. Optional: Record the pH measurement for the rain water. Is this acidic, basic or neutral? Write tap water beside the correct pH value on the pH scale.

C) Lemon Juice Experiment

1. Fill out the table below.

Total Drops of Lemon Juice Added	pH of the Water
0	

2. How does the pH of the water change as you add more drops of lemon juice? What is happening?

3. Approximately how many drops of lemon juice are required to reach a pH of 5?

4. Describe how the lemon juice experiment compares to the real world. What chemical is emitted from smelting operations that might have a similar effect as lemon juice in water? How does the chemical get from the smelter to the waterbody?

GROUNDRULES

MINING	AGE: 11 TO 13	LENGTH: 2 HR	CURRICULUM: earth science, careers

MINING CAREERS

Description

Students will explore the different types of careers available in the mining sector. They will identify careers shown on the *Ground Rules* film and write job descriptions.

VOCABULARY:

1. Career
2. Geologist
3. Engineer
4. Safety Inspector
5. Technician
6. Trades
7. Laborer
8. Apprentice
9. Job description
10. Skills

MATERIAL:

- *Ground Rules* film
- Pens and paper
- Resource books or internet access
- Optional: guest(s) from a local mining company

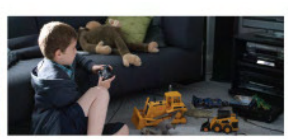
Introduction (Length: 45 minutes)

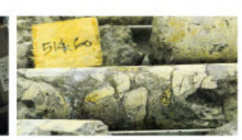
Watch the entire *Ground Rules* film one chapter at a time. Each chapter explores a unique aspect of mining:

Chapter 1: Exploration
Chapter 2: Open pit mining and ore processing
Chapter 4: Engineering and open pit mining
Chapter 5: Underground mining
Chapter 6: Community relations
Chapter 7: Environmental aspects of mining
Chapter 8: Reclamation
(note that Chapter 3 does not specifically include any mining occupations)

Pause the film after each chapter to allow the students to record their answers. Ask the students to list as many mining jobs as they can for each chapter (those that are shown in the film, plus any others they can think of). Review the answers and make a master list of potential mining careers on the board. Discuss the number and variety of positions available.





Activity I (Length: 30 minutes)

The objective of this activity is to identify what skills are necessary for various mining careers.

1. Have each student identify a mining career that they are interested in.

2. Using resource books, internet access, or discussions with friends and relatives that are employed in the mining industry, each student should identify the following:

    a. The day to day activities involved in this position.
    b. The skills required to perform work duties.
    c. The education and training required for the position.
    d. The safety training required for the position.

Activity II (Length: 30 minutes)

The objective of this activity is to learn about specific local mining careers.

1. If possible, invite a guest(s) that works in a local mining industry to visit the classroom.
2. Before the classroom visit, students should prepare a list of 5 questions they would ask the visitor(s) to find out more about the type of work they do.

Discussion (Length: 15 minutes)

Discuss the variety of options that are available for jobs in the mining industry.

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.

MINING	AGE: 11 TO 13	LENGTH: 2 HR	CURRICULUM: earth science, mine safety

MINE SAFETY AND HAZARD IDENTIFICATION

Description

Students will explore the potential safety hazards at mine sites and learn about methods used by mining companies to keep their workers safe. In the second activity, they will explore safety hazards at their school and identify safety measures to prevent accidents.

VOCABULARY:

1. Hazard
2. Personal protective equipment (PPE)
3. Safety measure
4. Safety training

MATERIALS:

- *Ground Rules* film
- Mine safety cards
- Masking tape
- Paper and pencils

Introduction (Length: 30 minutes)

Watch Chapter 2 “Modern Mining” and Chapter 5 “Going Underground” of the *Ground Rules* film. Both of these chapters address many safety protocols that are used in modern mines.

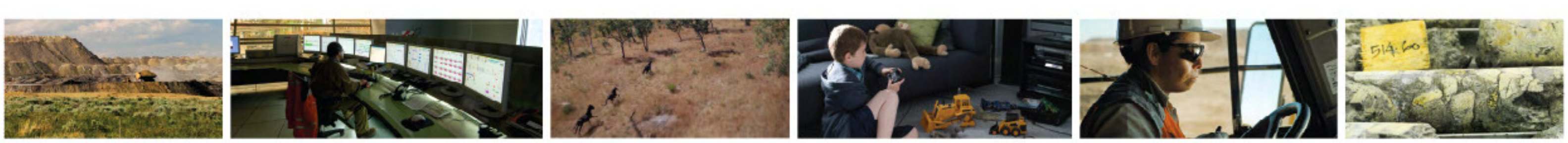
As a class, identify some of the safety hazards in open pit mining and underground mining. Make a list of the hazards on the board. What are some of the protective items miners wear to keep themselves safe? Explain that these items are called personal protective equipment or PPE for short.

Activity I (Length: 30 minutes)

The objective of this activity is to determine the appropriate safety measures to implement for each mining hazard.

Preparation:
1. Prepare a series of mine safety cards (one safety measure per card).

Activity:
1. Place the cards face down at the front of the class.
2. Ask the students to come up one by one and take a card.
3. Each student must tape the card on the board beside a mining hazard that can be prevented by implementing the safety measure on the card.



Activity II (Length: 30 minutes)

The objective of this activity is to identify safety hazards in the school.

1. Divide the students into groups of 3 or 4 students.
2. Send each group to a different area of the school (either inside or outside).
3. Each group has 15 minutes to identify as many hazards as they can in that area of the school. Then the groups should come back to the classroom and identify possible safety measures to implement to prevent accidents associated with the hazards they identified.

Discussion (Length: 30 minutes)

Activity I:
Review the answers as a class. Are there any errors? Could some of the cards be placed beside another hazard? Discuss the importance of health and safety training prior to working at a mine site and the importance of "thinking safety" at all times during mining.

Activity II:
What hazards were identified by students at school? What are some safety measures that could be implemented to prevent accidents associated with these hazards?

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

MINING

Mining
AGES 13-15

BUILDING AN OPEN-PIT MINE

Description

Students will build an open-pit mine and learn how ore is extracted from shallow ore bodies. They will stockpile the overburden and use it to reclaim the mine after operation.

VOCABULARY:

1. Open pit
2. Overburden
3. Benches
4. Slope
5. Truck route
6. Reclamation
7. Stockpile

MATERIALS:

- *Ground Rules* film
- Mixture of sand and pebbles
- Shredded paper or small wood chips
- Water
- Carving tools (scoops, spoons, spatulas, plastic knives)
- Ruler
- Large plastic or wooden boxes
- Small toy dump trucks and scoops
- Large buckets/pails (ore buckets)

Introduction (Length: 30 minutes)

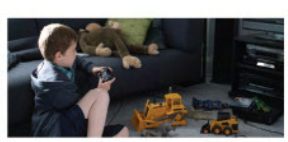
Watch Chapter 2 “Modern Mining” and Chapter 4 “Engineering Challenges” of the *Ground Rules* film (also optional: Chapter 8 “Reclamation”). Chapter 2 shows an open pit copper mine in Chile, while Chapter 4 shows an open pit gold and copper mine in Papua Indonesia. Pause the film to look at the structure of the open pit mines featured in each of these film chapters.

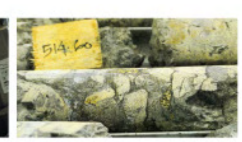
Under what circumstances are open pits used? Ask the students what they notice about the structure of these open pit mines. Discuss the function of the benches or stepped sides of the pit. Discuss the width to height ratio of the open pit structures. What would happen if the pit was deep and narrow? Explain that an open pit mine has to be wider than its depth to maintain a safe structure.

What equipment is used in the open pit mine? How does the size of this equipment compare to the equipment used in an underground mine?

What was the greatest challenge in building the open pit mine in Papua Indonesia? The ore body is at the top of a mountain. In some ways, this poses as great or an even greater challenge than sinking shafts to mine underground. Discuss the similarities and differences of open pit mining at the top of a mountain versus mining a deposit that is deep below the earth’s surface (e.g., tramway to reach the top versus cage and shaft to reach the bottom; hauling the ore down the mountain versus hauling the ore up to the surface; building a road to the top versus sinking a shaft and digging tunnels underground). The blasting and loading processes to remove the ore are similar.





Activity (Length: 45 minutes)

The objective of this activity is to build a model of an open pit mine and then reclaim the mine site.

1. Divide the class into groups of 3 or 4 students. Each group will build a model of an open pit mine. The goal is to build an open pit mine as deep as possible within the constraints of the box width and allowing room for stockpiling of overburden for reclamation.
2. Fill a large box approximately half full with the sand-pebble mixture. Add some water and mix it in to make a mixture that can be molded. Spread the mixture flat and pack it down.
3. Cover the entire mine site with shredded paper or wood chips. This represents the overburden layer and surface coverings (trees, vegetation).
4. Begin to create your open pit mine by removing the overburden layer and stockpiling it somewhere within your box. This must remain in place until the mine is ready to be reclaimed.
5. Using a variety of tools, begin to carve out the open pit mine. Create the benches on the sides. Use a ruler to measure and build benches of uniform height and width. Remember to make some wider benches for truck routes.
6. Discard the material dug out from the mine into the ore buckets.
7. Dig as deep into the mine as you can before the sides get too steep.
8. Use the wider benches to create a truck route from the top of the mine to the bottom. Use the toy trucks to determine the sizes of the truck routes (must be wide enough for two truck lanes).
9. After all of the open pit mines have been created and viewed by the teacher and other students, each group should reclaim their mine site. Remember that there is not enough overburden to fill the pit and the structure of the pit is made of rock, so it cannot be simply flattened. Encourage the students to be creative.

Discussion (Length: 15 minutes)

What were the challenges involved in creating the open pit mines? How much time did it take to dig out the mine, build the benches and truck routes? Discuss how much time it would have taken you to do this using the toy trucks and shovels (i.e., when the scale of the equipment used is proportional to the mine). Discuss the importance of large equipment to increase the efficiency of the open-pit mining process. What are the challenges of operating such large equipment?

What were the challenges involved in reclaiming the open pit mine? Where did each group decide to stockpile the overburden? How did this decision affect the way the open pit mine was built and its final size? Which group was able to create the largest open pit mine? How did each group use the stockpiled overburden to reclaim the landscape? Explain that in some cases, the open pit is filled with water to create a lake or filled with waste rock and the overburden is used to reclaim the portions of the site where buildings or other mining structures were located. Some of the overburden may also be used to create safe contours on the sides of the open pit and to create a landscape that looks natural.

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.

CROSS-SECTION MODEL OF AN UNDERGROUND MINE

Description

Students will build a cross-section model of an underground mine and learn how ore is extracted from deep ore deposits.

VOCABULARY:

1. Mine shaft
2. Headframe
3. Cage
4. Skip
5. Drift
6. Ventilation shaft
7. Stope
8. Ore body
9. Ore pass

MATERIALS:

- *Ground Rules* film
- Play dough (2 colors)
- Drinking straws
- Popsicle sticks, toothpicks
- Large squares of cardboard
- Markers and pencils
- Plastic knives and spoons
- String
- Small thread spools
- Miscellaneous craft items

Introduction (Length: 30 minutes)

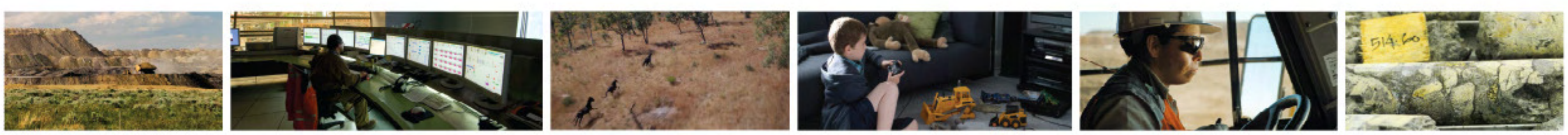
Watch Chapter 5 “Going Underground” of the *Ground Rules* film. Pause on the animated picture of the underground mine. Ask the students what the vertical and horizontal tunnels are called. What is one way (shown in the film) that underground mining has been made safer in recent years? (remote controlled vehicles)

Under what circumstances are underground mines used? Describe the process of underground mining. What are the components of an underground mine? What is the purpose of the headframe? Describe the cables and winch system that are located in the headframe to lower the cage of miners into the mine and haul out the ore in the skip. What is the purpose of the ventilation shaft? Explain that the ventilation shaft can also be used as an emergency escape route.

How do workers access the ore body from the shaft? Discuss the process of tunneling into the rock to create drifts to access the ore body. What is a stope? Discuss the process of blasting to loosen the ore.

How is the ore removed from the mine? Discuss the use of ore passes to deliver the ore from various drifts to the bottom of the mine where it may be crushed and raised to the surface in the skip.

If there are local underground mines in your area, use these as examples to illustrate the concept of underground mining.



Activity (Length: 45 minutes)

The objective of this activity is to build a cross-section model of an underground mine, showing all of the features that are present in actual underground mines.

1. Divide the class into groups of 3 to 4 students.
2. Each group will use a square of cardboard as the base for their model. They will be creating a vertical cross-section of an underground mine.
3. Each group should begin by drawing a line a few inches from the top of the cardboard square. This line is the ground surface. Above this line, draw the mine headframe and any other surface features of the mine.
4. Spread a layer of playdough (approximately 1 inch or 2.5 cm thick) over the entire surface of the cardboard below the surface line. The playdough represents the underground rock and soil.
5. Using a plastic knife, draw an irregular shape into the playdough that starts somewhere below the surface and extends to the bottom of the cardboard. This shape will represent the ore body. Cut out the shape and replace it with a different color of playdough.
6. Using plastic knives, spoons, popsicle sticks, straws and any other useful tools to dig out the playdough, construct the main mine shaft that will deliver workers into the mine and haul out the ore.
7. Use string and thread spools to set up the cable and pulley system for the main shaft and headframe.
8. Create a cage and skip out of popsicle sticks or pieces of cardboard. Attach these to the strings.
9. Construct a series of horizontal drifts that will be used to access the ore body from the main shaft.
10. Construct a ventilation shaft and will vent exhaust from the drifts to the surface and act as an emergency exit.
11. Create stopes in places along the drifts to access the ore body.
12. Create an ore pass that connects each drift, so that the rock can be sent down to the crusher and skip.
13. Make miners with toothpicks and/or playdough (be creative). Add miners to your underground cross-section. What are the miners doing in various regions of the mine?
14. Add playdough or cardboard vehicles to your underground mine. Where would they be located and what are their functions?
15. Let the models dry to harden.

Discussion (Length: 15 minutes)

Each group can use their model to explain the process of underground mining. They should describe all of the physical structures in their model and their purposes.

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Playdough Recipe

Combine 1 cup flour, ¼ cup salt, and 2 tablespoons cream of tartar with 1 cup water, 2 teaspoons food coloring and 1 tablespoon oil in a saucepan. Cook and stir 3-5 minutes, or until it sticks together in a ball. Knead for a few minutes on a lightly floured surface. Store in an air-tight container. You will need to make several batches of this recipe to have enough for this activity.

GROUNDRULES

MINING	AGE: 13 TO 15	LENGTH: 2 HR	CURRICULUM: earth science, chemistry, environment

MONITORING pH, TEMPERATURE, CONDUCTIVITY, D.O.

Description

Students will learn about environmental monitoring of water bodies at mine sites. They will test water quality parameters (pH, temperature, conductivity and dissolved oxygen) at a local water body.

VOCABULARY:

1. Acidic
2. Basic
3. Neutral
4. pH
5. Temperature
6. Water quality
7. Samples
8. Acid rain
9. Sulfur dioxide
10. Conductivity
11. Dissolved oxygen
12. Baseline water quality

MATERIALS:

- *Ground Rules* film
- Hand-held water quality probes (pH, dissolved oxygen, conductivity)
- Waterproof thermometer
- Hip or chest waders, rubber boots
- Life jackets
- Clipboard
- Optional: Small plastic bottles with lids
- Maps of the water bodies (can be hand drawn)
- Optional: GPS unit
- Field data sheets (provided)

Introduction (Length: 30 minutes)

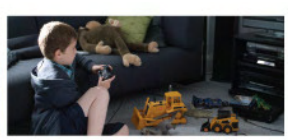
Watch Chapter 7 “Mining and the Environment” of the *Ground Rules* film. This chapter shows an example of how potential environmental impacts of a mine site were minimized at the McArthur River Mine in Australia.

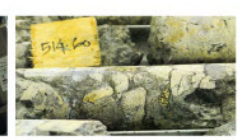
Ask the students to name some of the possible environmental impacts of a mine (for example: water quality, air quality, land disturbance, removal of vegetation/habitat).

What major environmental challenge did Xstrata have to overcome before it could open the McArthur River Mine? (re-routing of the river). Discuss the challenges associated with rerouting the river (maintaining biodiversity, maintaining natural features of a river channel, water quality).

What does an environmental technician do at a mine site? Explain that in this activity, the students will be the “environmental technicians” of a hypothetical mine site. They will collect water samples and test them for pH, temperature, conductivity and dissolved oxygen. These are the most common parameters tested for general water quality.





Temperature:
Why is water temperature important to measure? Abnormally warm water may reduce the ability of the water to hold dissolved oxygen which is necessary for aquatic life. Dissolved oxygen can also be measured directly with a special probe.

pH:
Review the pH scale and what is meant by the terms acidic, basic and neutral. The pH scale ranges from 0 to 14, with 7 being neutral. Numbers below 7 are acidic, while numbers above 7 are basic. The pH scale is logarithmic, so each number represents a 10-fold change. For example, a change from pH 7 to pH 6 means the acidity of the solution has increased by 10 times.

The pH of normal rainwater is slightly acidic (pH 5.6) due to the presence of carbon dioxide gas. The pH of many water bodies ranges from 6 to 8. Fish and aquatic organisms begin to be affected when the pH drops below 5.

pH Scale:

0 1 2 3 4 5 6 $\boxed{7}$ 8 9 10 11 12 13 14

← increasingly acidic | neutral | increasingly basic →

Conductivity:
Ask the students if they know what conductivity is and why it is measured to determine water quality. Conductivity is a measure of how well a liquid conducts electricity. Pure water has zero conductivity. The more ions that are in solution in the liquid, the more electricity it will be able to conduct. Sea water has a greater conductivity than fresh water. A conductivity meter can be used in water quality monitoring to measure the electrical conductivity of the water. This is an indirect measurement of the amount of ions (salts) that are in solution. Conductivity is usually measured in units of µS/cm (micro-siemens per centimeter).

Dissolved oxygen:
A special probe can be used to directly measure the amount of oxygen that is dissolved in the water. Dissolved oxygen is important for the survival of aquatic organisms. Dissolved oxygen is usually measured in units of mg/L (mg or gas per liter of water).

Explain that water quality monitoring at a mine site is conducted in order to evaluate possible changes that have occurred as a result of mining activities. Explain that each water body has a unique natural chemistry and therefore there is not a standard pH, conductivity or dissolved oxygen value that is considered “normal” for all water bodies. Therefore, before the mine site is developed, water quality in each local water body that may be impacted by the mine is tested, so that there is a record of what is “normal” for each water body. This is usually called baseline water quality. Then, after the mine is in operation, the water can be tested on a regular basis and compared to the baseline values to see if there has been a change in water quality. A change in any of these parameters may indicate a change in the chemistry of the water body.

Activity (Length: 60 minutes at field location + travel time)

The objective of this activity is to collect and test water samples from a local water body for pH, temperature, conductivity and dissolved oxygen.

1. Follow the manufacturer's directions to calibrate the pH, conductivity and dissolved oxygen meters in the classroom before going to the field location.
2. Visit a local water body (lake or stream). For safety reasons, avoid fast-flowing rivers. Bring small plastic bottles, a thermometer, water quality meters, maps, field data sheets, waders/rubber boots and life jackets.
3. For safety reasons, wear a life jacket at all times while water sampling.
4. Select three sampling sites. As accurately as possible, plot each sampling point on a map of the water body. Optional: use a GPS unit to collect coordinates at each site. These can be used to accurately plot the sampling location on a topographic map.
5. At each site, hold the thermometer in the water for a minute. Record the temperature on the field data sheet. Take three readings. Record the individual readings. When you return to the classroom, calculate the average reading.
6. Test the pH, conductivity and dissolved oxygen using the hand-held probes. Take three readings. Record the individual readings. When you return to the classroom, calculate the average reading.
7. At each sampling point, record any observations on the data sheet that may be important to interpreting the information, such as clarity of the water, potential nearby pollution sources, runoff water entering the water body, etc. If applicable, pollution sources can be plotted on the maps as well.
8. Optional: Collect a sample of water in a small plastic bottle from each site. Seal tightly. These can be used to retest parameters in the classroom or to conduct further experiments.
9. Return to the classroom.
10. Calculate the average field readings and record on the data sheet.

Discussion (Length: 30 minutes)

How did the water quality compare between sites along one water body? If there was a difference, ask the students which site they think is potentially more polluted. Why? Did they observe any potential pollution sources that might affect water quality at that site?

How might a mine site affect the temperature of a nearby water body? This could occur if the mine discharges warm water into a local water body. Explain that modern mines have a responsibility to protect the environment surrounding the mine. If they discharge water to the environment, they must ensure that the quality and temperature of the water is suitable to protect aquatic organisms and their habitat.

How might emissions from a mine site affect the pH of a nearby water body? Explain that a chemical called sulfur dioxide is released to the air during the smelting process. In the atmosphere, sulfur dioxide combines with water and produces acid rain. When acid rain falls onto a water body it can make the water acidic over time. Explain how modern mines install pollution control equipment to minimize the amount of sulfur dioxide released.

Which is potentially more polluted? Why?

a) a site with high conductivity or a site with low conductivity
b) a site with high dissolved oxygen or a site with low dissolved oxygen

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.

Field Data Sheet

Site 1

Parameter	Reading 1	Reading 2	Reading 3	Average
temperature				
pH				
conductivity				
dissolved oxygen				

Observations:

Optional: GPS Coordinates ____

Site 2

Parameter	Reading 1	Reading 2	Reading 3	Average
temperature				
pH				
conductivity				
dissolved oxygen				

Observations:

Optional: GPS Coordinates ____

Site 3

Parameter	Reading 1	Reading 2	Reading 3	Average
temperature				
pH				
conductivity				
dissolved oxygen				

Observations:

Optional: GPS Coordinates ____

GROUNDRULES

MINING | AGE: 13 TO 15 | LENGTH: 2 HR | CURRICULUM: earth science, careers

MINING CAREERS

Description

Students will explore the different types of careers available in the mining sector. They will identify careers shown on the *Ground Rules* film and write job descriptions. They will conduct mock interviews for various mining careers.

VOCABULARY:

1. Career
2. Geologist
3. Engineer
4. Safety Inspector
5. Technician
6. Trades
7. Laborer
8. Apprentice
9. Job description
10. Skills

MATERIAL:

- *Ground Rules* film
- Pens and paper
- Resource books or internet access
- Optional: guest(s) from a local mining company

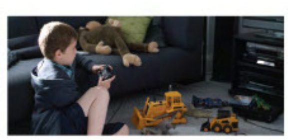
Introduction (Length: 45 minutes)

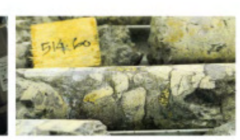
Watch the entire *Ground Rules* film one chapter at a time. Each chapter explores a unique aspect of mining:

Chapter 1: Exploration
Chapter 2: Open pit mining and ore processing
Chapter 4: Engineering and open pit mining
Chapter 5: Underground mining
Chapter 6: Community relations
Chapter 7: Environmental aspects of mining
Chapter 8: Reclamation
(note that Chapter 3 does not specifically include any mining occupations)

Pause the film after each chapter to allow the students to record their answers. Ask the students to list as many mining jobs as they can for each chapter (those that are shown in the film, plus any others they can think of). Review the answers and make a master list of potential mining careers on the board. Discuss the number and variety of positions available.





Activity I (Length: 30 minutes)

The objective of this activity is to identify what skills are necessary for various mining careers.

1. Have each student identify a mining career that they are interested in.

2. Using resource books, internet access, or discussions with friends and relatives that are employed in the mining industry, each student should identify the following:

    a. The day to day activities involved in this position.
    b. The skills required to perform work duties.
    c. The education and training required for the position.
    d. The safety training required for the position.

3. Divide the students into pairs. Using the job descriptions identified in #2, have one person of each pair pretend to be the applicant and one person pretend to be the employer. The students will conduct a mock interview by taking turns asking questions. After 15 minutes, the pairs should switch roles.

Activity II (Length: 30 minutes)

The objective of this activity is to learn about specific local mining careers.

1. If possible, invite a guest(s) that works in a local mining industry to visit the classroom.
2. Before the classroom visit, students should prepare a list of 5 questions they would ask the visitor(s) to find out more about the type of work they do.

Discussion (Length: 15 minutes)

Discuss the variety of options that are available for jobs in the mining industry. Ask the students who played the role of employer whether they would have hired the applicant. Why or why not?

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.

MINE SAFETY AND MINING ACCIDENTS

Description

Students will explore the potential safety hazards at mine sites and learn about methods used by mining companies to keep their workers safe. In the second activity, they will research a major mining disaster and discuss the lessons learned from it.

VOCABULARY:

1. Hazard
2. Personal protective equipment (PPE)
3. Safety measure
4. Safety training

MATERIALS:

- *Ground Rules* film
- Mine safety cards
- Masking tape
- Paper and pencils
- Resource books or internet access

Introduction (Length: 30 minutes)

Watch Chapter 2 “Modern Mining” and Chapter 5 “Going Underground” of the *Ground Rules* film. Both of these chapters address many safety protocols that are used in modern mines.

As a class, identify some of the safety hazards in open pit mining and underground mining. Make a list of the hazards on the board. What are some of the protective items miners wear to keep themselves safe? Explain that these items are called personal protective equipment or PPE for short.

Activity I (Length: 30 minutes)

The objective of this activity is to determine the appropriate safety measures to implement for each mining hazard.

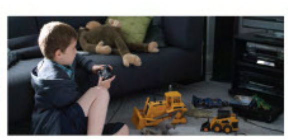
Preparation:

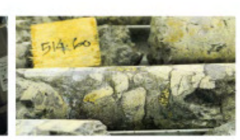
1. Prepare a series of mine safety cards (one safety measure per card).

Activity:

1. Place the cards face down at the front of the class.
2. Ask the students to come up one by one and take a card.
3. Each student must tape the card on the board beside a mining hazard that can be prevented by implementing the safety measure on the card.





Activity II (Length: 30 minutes)

The objective of this activity is to research a major mining accident. Students can work alone or in pairs.

1. Using resource books or internet access, research a major mining accident that happened in your country, state or province. If possible, have each student or group research a different mining disaster.
2. When did the accident occur?
3. How many people were killed or injured?
4. Identify the safety hazard and why the accident happened.
5. Could the accident have been prevented? How?
6. What effect did that accident have on the miners? the mine? the community?
7. What was learned from this accident? What safety measures were implemented to prevent it from happening again?

Discussion (Length: 30 minutes)

Activity I:
Review the answers as a class. Are there any errors? Could some of the cards be placed beside another hazard? Discuss the importance of health and safety training prior to working at a mine site and the importance of “thinking safety” at all times during mining.

Activity II:
Have each group present their findings to the class. Discuss the lessons learned from the accidents and how modern mines are operating more safely. Also discuss the inherent dangers involved in mining and that even with strong safety protocols, accidents can and do still occur.

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

MINING

Mining

AGES 15-18

GROUND**RULES**

MINING	AGE: 15 TO 18	LENGTH:1.5 HR	CURRICULUM: earth science, mining

BUILDING AN OPEN-PIT MINE

Description

Students will build an open-pit mine and learn how ore is extracted from shallow ore bodies. They will stockpile the overburden and use it to reclaim the mine after operation. They will draw a cross-sectional diagram of the open pit mine.

VOCABULARY:

1. Open pit
2. Overburden
3. Benches
4. Slope
5. Truck route
6. Reclamation
7. Stockpile
8. Cross-sectional diagram

MATERIALS:

- *Ground Rules* film
- Mixture of sand and pebbles
- Shredded paper or small wood chips
- Water
- Carving tools (scoops, spoons, spatulas, plastic knives)
- Ruler
- Large plastic or wooden boxes
- Small toy dump trucks and scoops
- Large buckets/pails (ore buckets)
- Paper and pencils

Introduction (Length: 30 minutes)

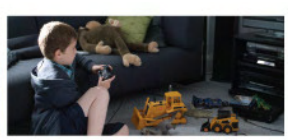
Watch Chapter 2 “Modern Mining” and Chapter 4 “Engineering Challenges” of the *Ground Rules* film (also optional: Chapter 8 “Reclamation”). Chapter 2 shows an open pit copper mine in Chile, while Chapter 4 shows an open pit gold and copper mine in Papua Indonesia. Pause the film to look at the structure of the open pit mines featured in each of these film chapters.

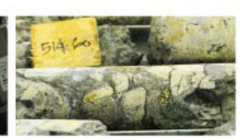
Under what circumstances are open pits used? Ask the students what they notice about the structure of these open pit mines. Discuss the function of the benches or stepped sides of the pit. Discuss the width to height ratio of the open pit structures. What would happen if the pit was deep and narrow? Explain that an open pit mine has to be wider than its depth to maintain a safe structure.

What equipment is used in the open pit mine? How does the size of this equipment compare to the equipment used in an underground mine?

What was the greatest challenge in building the open pit mine in Papua Indonesia? The ore body is at the top of a mountain. In some ways, this poses as great or an even greater challenge than sinking shafts to mine underground. Discuss the similarities and differences of open pit mining at the top of a mountain versus mining a deposit that is deep below the earth’s surface (e.g., tramway to reach the top versus cage and shaft to reach the bottom; hauling the ore down the mountain versus hauling the ore up to the surface; building a road to the top versus sinking a shaft and digging tunnels underground). The blasting and loading processes to remove the ore are similar.





Activity (Length: 45 minutes)

The objective of this activity is to build a model of an open pit mine and then reclaim the mine site.

1. Divide the class into groups of 3 or 4 students. Each group will build a model of an open pit mine. The goal is to build an open pit mine as deep as possible within the constraints of the box width and allowing room for stockpiling of overburden for reclamation.
2. Fill a large box approximately half full with the sand-pebble mixture. Add some water and mix it in to make a mixture that can be molded. Spread the mixture flat and pack it down.
3. Cover the entire mine site with shredded paper or wood chips. This represents the overburden layer and surface coverings (trees, vegetation).
4. Begin to create your open pit mine by removing the overburden layer and stockpiling it somewhere within your box. This must remain in place until the mine is ready to be reclaimed.
5. Using a variety of tools, begin to carve out the open pit mine. Create the benches on the sides. Use a ruler to measure and build benches of uniform height and width. Remember to make some wider benches for truck routes.
6. Discard the material dug out from the mine into the ore buckets.
7. Dig as deep into the mine as you can before the sides get too steep.
8. Use the wider benches to create a truck route from the top of the mine to the bottom. Use the toy trucks to determine the sizes of the truck routes (must be wide enough for two truck lanes).
9. Draw a cross-sectional diagram of the open pit mine (to scale as much as possible). Use a ruler to measure depths and widths of benches, etc.
10. After all of the open pit mines have been created and viewed by the teacher and other students, each group should reclaim their mine site. Remember that there is not enough overburden to fill the pit and the structure of the pit is made of rock, so it cannot be simply flattened. Encourage the students to be creative.

Discussion (Length: 15 minutes)

What were the challenges involved in creating the open pit mines? How much time did it take to dig out the mine, build the benches and truck routes? Discuss how much time it would have taken you to do this using the toy trucks and shovels (i.e., when the scale of the equipment used is proportional to the mine). Discuss the importance of large equipment to increase the efficiency of the open-pit mining process. What are the challenges of operating such large equipment?

What were the challenges involved in reclaiming the open pit mine? Where did each group decide to stockpile the overburden? How did this decision affect the way the open pit mine was built and its final size? Which group was able to create the largest open pit mine? How did each group use the stockpiled overburden to reclaim the landscape? Explain that in some cases, the open pit is filled with water to create a lake or filled with waste rock and the overburden is used to reclaim the portions of the site where buildings or other mining structures were located. Some of the overburden may also be used to create safe contours on the sides of the open pit and to create a landscape that looks natural.

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

MINING | AGE: 15 TO 18 | LENGTH: 1.5HR | CURRICULUM: earth science, mining

BUILDING A 3-DIMENSIONAL UNDERGROUND MINE

Description

Students will build a 3-dimensional model of an underground mine with a functional pulley system to operate the skip and cage. They will learn how ore is extracted from deep ore deposits.

VOCABULARY:

1. Mine shaft
2. Headframe
3. Cage
4. Skip
5. Drift
6. Ventilation shaft
7. Stope
8. Ore body
9. Ore pass

MATERIALS:

- *Ground Rules* film
- Plastic 1 and 2 inch plumbing pipes (straight pieces, joiners, elbows, T-shapes, etc.)
- String
- Small pulleys
- Pencils and paper
- Cardboard
- Markers
- Miscellaneous craft items
- Sand or small pebbles
- Straws, sticks or long-handled narrow spoons
- Glue (optional)

Introduction (Length: 30 minutes)

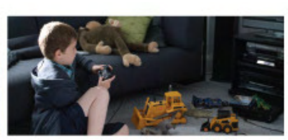
Watch Chapter 5 “Going Underground” of the *Ground Rules* film. Pause on the animated picture of the underground mine. Ask the students what the vertical and horizontal tunnels are called. What is one way (shown in the film) that underground mining has been made safer in recent years? (remote controlled vehicles)

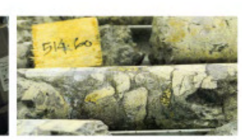
Under what circumstances are underground mines used? Describe the process of underground mining. What are the components of an underground mine? What is the purpose of the headframe? Describe the cables and winch system that are located in the headframe to lower the cage of miners into the mine and haul out the ore in the skip. What is the purpose of the ventilation shaft? Explain that the ventilation shaft can also be used as an emergency escape route.

How do workers access the ore body from the shaft? Discuss the process of tunneling into the rock to create drifts to access the ore body. What is a stope? Discuss the process of blasting to loosen the ore.

How is the ore removed from the mine? Discuss the use of ore passes to deliver the ore from various drifts to the bottom of the mine where it may be crushed and raised to the surface in the skip.





If there are local underground mines in your area, use these as examples to illustrate the concept of underground mining.

Activity (Length: 45 minutes)

The objective of this activity is to build a 3-dimensional, functional model of an underground mine, showing all of the features that are present in actual underground mines.

1. Divide the class into groups of 3 to 4 students. Each group will create a unique 3-dimensional functional model of an underground mine.
2. Begin by sketching a design on paper. Include the main shaft, a ventilation shaft, at least 3 drifts, 1 stope per drift, and an ore pass that connects the drifts.
3. Using the plastic plumbing pipes, create a 3-dimensional structure of the sketched underground mine. Create the mine shaft using the larger diameter pipes. Use the smaller diameter pipes to build the drifts and the ore pass.
4. Create a stope on each drift using a T-shaped joiner pipe with one opening pointing upwards (to simulate an opening into the ore body).
5. Using cardboard and various craft materials, design a headframe, a cage and a skip. Use string and pulleys to set up a functional cable and pulley system inside the headframe to lift and lower the cage and skip.
6. Create a door on the skip that can be raised and lowered from a cable in the headframe.
7. Stand the model up vertically in a physical support or have one student hold it firmly.
8. Test out the model by adding some sand or small pebbles (ore) to one of the stopes in one of the drifts (through the opening on the T-shaped joiner pipe). Use sticks, straws or long handled spoons to push or pull the ore to the ore pass opening on that drift. Allow the ore to fall to the bottom of the ore pass. Raise the door on the skip to allow the ore to enter the skip. Then close the skip door and raise the skip to the surface.
9. Optional: Glue the pipe pieces together to make a permanent model.

Discussion (Length: 15 minutes)

Each group can use their model to explain the process of underground mining. They should describe all of the physical structures in their model and their purposes. What were the challenges involved in building the underground structure? When each model was tested, were there any areas where the ore was blocked from passing through? Discuss the challenges involved in building a real underground mine.

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.

DESIGNING A MINE

Description

Students will design a mine to extract ore from a hypothetical ore body.

VOCABULARY:

1. Ore body
2. Open pit mine
3. Underground mine
4. Mine shaft
5. Headframe
6. Drifts
7. Mine design

MATERIAL:

- *Ground Rules* film
- Paper and pencils
- Rulers
- Cross-sectional mine diagrams

Introduction (Length: 30 minutes)

Watch Chapters 1, 2 and 5 of the *Ground Rules* film. Chapter 1 “Exploration” shows how geologists map out the ore deposit. Chapter 2 “Modern Mining” shows how ore is extracted from an open pit mine. Chapter 5 “Going Underground” shows how ore is extracted from an underground mine.

Review the structure of open pit and underground mines. What are the main criteria used to decide which type of mine will be developed? Discuss the components of an underground mine and an open pit mine and review terminology.

Activity (Length: 30 minutes)

The objective of this activity is to design a mine based on a cross-sectional diagram of an ore body. The students will decide what type of mine would be the best to access the ore body and how the mine should be designed.

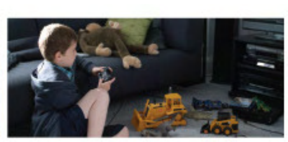
Preparation:

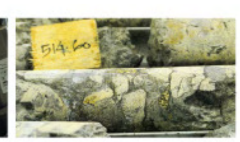
1. Use the attached diagram as an example of a cross-section of an ore body. Prepare a variety of these for different groups of students to work on.

Activity:

1. Divide the class into groups of 2 or 3 students. Give each group a different cross-sectional ore body diagram.
2. Each group must design a mine to extract the ore from the ore body. They should decide which would be most efficient – an open pit or an underground mine or both to access different parts of the deposit.





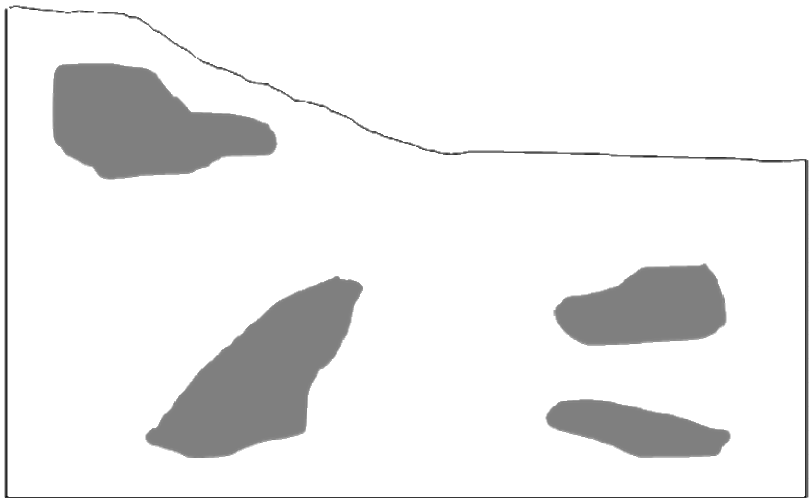
3. If they are designing an underground mine, they should draw the location of the mine shaft and drifts to access the ore bodies.
4. Optional: They could also draw a cross-sectional diagram of the open pit mine to show the benches and truck routes.

Discussion (Length: 30 minutes)

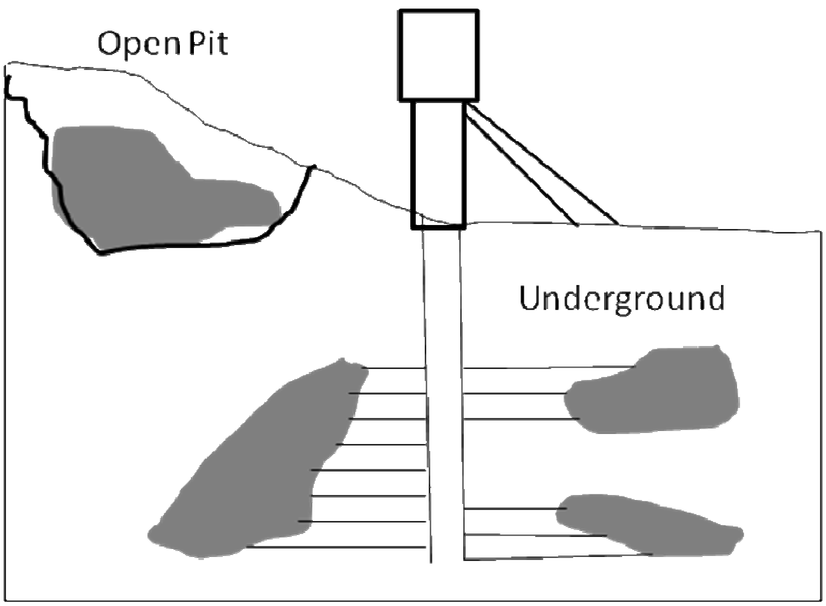
Each group should present their mine design to the class and explain how they designed the mine to efficiently extract all of the ore.

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.

Example of a Cross-Sectional Diagram of an Ore Body



Example of a Mine Design based on the Ore Body



GROUNDRULES

MINING	AGE: 15 TO 18	LENGTH:3 HR	CURRICULUM:earth science, chemistry, environment

MONITORING pH, TEMPERATURE, CONDUCTIVITY, D.O.

Description

Students will learn about environmental monitoring of water bodies at mine sites. They will test water quality parameters (pH, temperature, conductivity and dissolved oxygen) at a local water body. In the second activity, they will explore the property of conductivity in more depth with a classroom experiment.

VOCABULARY:

1. Acidic
2. Basic
3. Neutral
4. pH
5. Temperature
6. Water quality
7. Samples
8. Acid rain
9. Sulfur dioxide
10. Conductivity
11. Dissolved oxygen
12. Baseline water quality

MATERIALS:

- *Ground Rules* film
- Hand-held water quality probes (pH, dissolved oxygen, conductivity)
- Waterproof thermometer
- Hip or chest waders, rubber boots
- Life jackets
- Clipboard
- Small plastic bottles with lids
- Maps of the water bodies (can be hand drawn)
- Optional: GPS unit
- Field data sheets (provided)
- Two beakers
- Three alligator clips
- Deionized water, salt
- Light bulb with two metal tabs on the base
- Battery

Introduction (Length: 30 minutes)

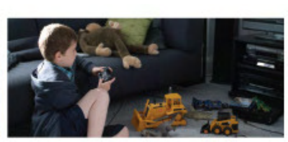
Watch Chapter 7 “Mining and the Environment” of the *Ground Rules* film. This chapter shows an example of how potential environmental impacts of a mine site were minimized at the McArthur River Mine in Australia.

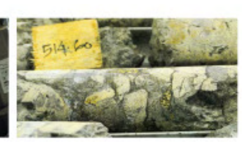
Ask the students to name some of the possible environmental impacts of a mine (for example: water quality, air quality, land disturbance, removal of vegetation/habitat).

What major environmental challenge did Xstrata have to overcome before it could open the McArthur River Mine? (re-routing of the river). Discuss the challenges associated with rerouting the river (maintaining biodiversity, maintaining natural features of a river channel, water quality).

What does an environmental technicians do at a mine site? Explain that in this activity, the students will be the “environmental technicians” of a hypothetical mine site. They will collect water samples and test them for pH, temperature, conductivity and dissolved oxygen. These are the most common parameters tested for general water quality.





Temperature:
Why is water temperature important to measure? Abnormally warm water may reduce the ability of the water to hold dissolved oxygen which is necessary for aquatic life. Dissolved oxygen can also be measured directly with a special probe.

pH:
Review the pH scale and what is meant by the terms acidic, basic and neutral. The pH scale ranges from 0 to 14, with 7 being neutral. Numbers below 7 are acidic, while numbers above 7 are basic. The pH scale is logarithmic, so each number represents a 10-fold change. For example, a change from pH 7 to pH 6 means the acidity of the solution has increased by 10 times.

The pH of normal rainwater is slightly acidic (pH 5.6) due to the presence of carbon dioxide gas. The pH of many water bodies ranges from 6 to 8. Fish and aquatic organisms begin to be affected when the pH drops below 5.

pH Scale:

0 1 2 3 4 5 6 $\boxed{7}$ 8 9 10 11 12 13 14

← increasingly acidic   neutral   increasingly basic →

Conductivity:
Ask the students if they know what conductivity is and why it is measured to determine water quality. Conductivity is a measure of how well a liquid conducts electricity. Pure water has zero conductivity. The more ions that are in solution in the liquid, the more electricity it will be able to conduct. Sea water has a greater conductivity than fresh water. A conductivity meter can be used in water quality monitoring to measure the electrical conductivity of the water. This is an indirect measurement of the amount of ions (salts) that are in solution. Conductivity is usually measured in units of µS/cm (micro-siemens per centimeter).

Dissolved oxygen:
A special probe can be used to directly measure the amount of oxygen that is dissolved in the water. Dissolved oxygen is important for the survival of aquatic organisms. Dissolved oxygen is usually measured in units of mg/L (mg or gas per liter of water).

Explain that water quality monitoring at a mine site is conducted in order to evaluate possible changes that have occurred as a result of mining activities. Explain that each water body has a unique natural chemistry and therefore there is not a standard pH, conductivity or dissolved oxygen value that is considered “normal” for all water bodies. Therefore, before the mine site is developed, water quality in each local water body that may be impacted by the mine is tested, so that there is a record of what is “normal” for each water body. This is usually called baseline water quality. Then, after the mine is in operation, the water can be tested on a regular basis and compared to the baseline values to see if there has been a change in water quality. A change in any of these parameters may indicate a change in the chemistry of the water body.

Activity I (Length: 90 minutes at field location + travel time)

The objective of this activity is to collect and test water samples from a local water body for pH, temperature, conductivity and dissolved oxygen.

1. Follow the manufacturer's directions to calibrate the pH, conductivity and dissolved oxygen meters in the classroom before going to the field location.
2. Visit a local water body (lake or stream). For safety reasons, avoid fast-flowing rivers. Bring small plastic bottles, a thermometer, water quality meters, maps, field data sheets, waders/rubber boots and life jackets.
3. For safety reasons, wear a life jacket at all times while water sampling.
4. Select 5-10 sampling sites. As accurately as possible, plot each sampling point on a map of the water body. Optional: use a GPS unit to collect coordinates at each site. These can be used to accurately plot the sampling location on a topographic map.
5. At each site, hold the thermometer in the water for a minute. Record the temperature on the field data sheet. Take three readings. Record the individual readings. When you return to the classroom, calculate the average reading.
6. Test the pH, conductivity and dissolved oxygen using the hand-held probes. Take three readings. Record the individual readings. When you return to the classroom, calculate the average reading.
7. At each sampling point, record any observations on the data sheet that may be important to interpreting the information, such as clarity of the water, potential nearby pollution sources, runoff water entering the water body, etc. If applicable, pollution sources can be plotted on the maps as well.
8. Collect a sample of water in a small plastic bottle from each site. Seal tightly. These will be used in Activity II.
9. Return to the classroom.
10. Calculate the average field readings and record on the data sheet.

Activity II (Length: 30 minutes)

The objective of this activity is to further explore the concept of conductivity in a classroom experiment.

1. Set up a conductivity tester. Clip one end of an alligator clip to the negative end of the battery and leave the other end hanging loose. Clip a second alligator clip to the positive end of the battery and the other end to one tab on the light bulb. Clip the third alligator clip to the other tab on the light bulb and leave the other end hanging loose.
2. Fill one beaker with deionized water. Put the loose alligator clips from each end of the conductor into the water. Observe the light bulb. What happens? Record your observations.
3. In the second beaker, add a teaspoon of salt to the water. Put the loose alligator clips into the water. Observe the light bulb. What happens? Record your observations.
4. Add more salt slowly to the second beaker. Record your observations.
5. Test the conductivity of the samples you collected from the water body.
6. For safety reasons, disconnect the battery promptly when you are finished the experiment.

Discussion (Length: 30 minutes)

Activity I:
How did the water quality compare between sites along one water body? If there was a difference, ask the students which site they think is potentially more polluted. Why? Did they observe any potential pollution sources that might affect water quality at that site?

How might a mine site affect the temperature of a nearby water body? This could occur if the mine discharges warm water into a local water body. Explain that modern mines have a responsibility to protect the environment surrounding the mine. If they discharge water to the environment, they must ensure that the quality and temperature of the water is suitable to protect aquatic organisms and their habitat.

How might emissions from a mine site affect the pH of a nearby water body? Explain that a chemical called sulfur dioxide is released to the air during the smelting process. In the atmosphere, sulfur dioxide combines with water and produces acid rain. When acid rain falls onto a water body it can make the water acidic over time. Explain how modern mines install pollution control equipment to minimize the amount of sulfur dioxide released.

Which is potentially more polluted? Why?

a) a site with high conductivity or a site with low conductivity
b) a site with high dissolved oxygen or a site with low dissolved oxygen

Activity II:
Does the deionized water make the light bulb work? Why or why not?
Does the salt water make the light bulb work? Why or why not?
How does increasing the salt content affect the light bulb?
How did the results of conductivity testing of the water body samples compare to the meter measurements?

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.

Field Data Sheet

Site 1

Parameter	Reading 1	Reading 2	Reading 3	Average
temperature				
pH				
conductivity				
dissolved oxygen				

Observations:

Optional: GPS Coordinates ____

Site 2

Parameter	Reading 1	Reading 2	Reading 3	Average
temperature				
pH				
conductivity				
dissolved oxygen				

Observations:

Optional: GPS Coordinates ____

Site 3

Parameter	Reading 1	Reading 2	Reading 3	Average
temperature				
pH				
conductivity				
dissolved oxygen				

Observations:

Optional: GPS Coordinates ____

Site 4

Parameter	Reading 1	Reading 2	Reading 3	Average
temperature				
pH				
conductivity				
dissolved oxygen				

Observations:

Optional: GPS Coordinates ____

Site 5

Parameter	Reading 1	Reading 2	Reading 3	Average
temperature				
pH				
conductivity				
dissolved oxygen				

Observations:

Optional: GPS Coordinates ____

GROUNDRULES

MINING	AGE: 15 TO 18	LENGTH: 2 HR	CURRICULUM: earth science, careers

MINING CAREERS

Description

Students will explore the different types of careers available in the mining sector. They will identify careers shown on the *Ground Rules* film and write job descriptions. They will go through the process of applying for a job of their choice in the mining industry.

VOCABULARY:

1. Career
2. Geologist
3. Engineer
4. Safety Inspector
5. Technician
6. Trades
7. Laborer
8. Apprentice
9. Job description
10. Skills
11. Resume
12. Cover letter

MATERIAL:

- *Ground Rules* film
- Pens and paper
- Resource books or internet access
- Optional: guest(s) from a local mining company
- Optional: examples of resumes and cover letters

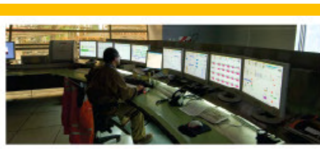
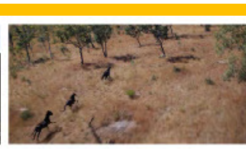
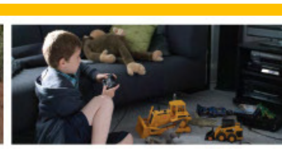
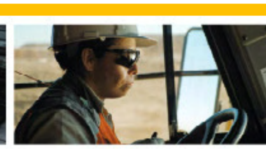
Introduction (Length: 45 minutes)

Watch the entire *Ground Rules* film one chapter at a time (except for Chapter 3). Each chapter explores a unique aspect of mining and mining occupations:

Chapter 1: Exploration
Chapter 2: Open pit mining and ore processing
Chapter 4: Engineering and open pit mining
Chapter 5: Underground mining
Chapter 6: Community relations
Chapter 7: Environmental aspects of mining
Chapter 8: Reclamation
(note that Chapter 3 does not specifically include any mining occupations)

Pause the film after each chapter to allow the students to record their answers. Ask the students to list as many mining jobs as they can for each chapter (those that are shown in the film, plus any others they can think of). Review the answers and make a master list of potential mining careers on the board. Discuss the number and variety of positions available.

Review the components of a resume and cover letter. Discuss the items that need to be included and how to use these tools to convince employers that they are the best candidate for the position.


Activity I (Length: 30 minutes)

The objective of this activity is to identify what skills are necessary for a mining career that is interesting to each student and to prepare a resume and cover letter to apply for a position at a fictitious mining company.

1. Have each student identify a mining career that they are interested in.

2. Using resource books, internet access, or discussions with friends and relatives that are employed in the mining industry, each student should identify the following:

    a. The day to day activities involved in this position.
    b. The skills required to perform work duties.
    c. The education and training required for the position.
    d. The safety training required for the position.

3. Based on the information collected in #2, prepare a resume and cover letter to apply for a position at a local mine.

Activity II (Length: 30 minutes)

The objective of this activity is to learn about specific local mining careers.

1. If possible, invite a guest(s) that works in a local mining industry to visit the classroom.
2. Before the classroom visit, students should prepare a list of 5 questions they would ask the visitor(s) to find out more about the type of work they do.

Discussion (Length: 15 minutes)

Discuss the variety of options that are available for jobs in the mining industry.

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

MINING PROCESSES

Mining Processes

AGES 11-13

MASS, VOLUME, DENSITY AND SPECIFIC GRAVITY

Description

Students will determine the mass, volume, density and specific gravity of different materials and compare them to the density of gold. They will learn how these properties enabled early miners to pan for gold.

VOCABULARY:

1. Mass
2. Volume
3. Density
4. Specific gravity
5. Panning for gold

MATERIALS:

- *Ground Rules* film
- Graduated cylinder (millimeter intervals)
- Water
- String
- Balance scale with weights
- Calculator
- Copper pennies
- Lead fishing weights
- Iron carpenter's nails
- Quartz rock
- Granite rock
- "Mystery" materials brought in by students

Introduction (Length: 20 minutes)

Watch Chapter 1 "Exploration" of the *Ground Rules* film. Focus on the section where the geologists are panning for gold in the creek.

Ask the students if they have ever tried panning for gold. Do they know how it works? How do geologists separate the gold from the water and other rocks, sand and silt? The answer has to do with the properties of mass, volume, density and specific gravity.

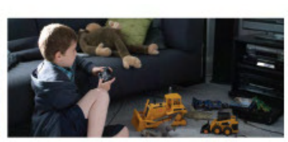
Review the concepts of mass and volume. When we weigh a material, we are determining its mass. When we find out how much space the material occupies, we are determining its volume.

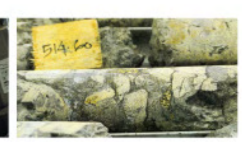
Density is the ratio between the mass and the volume of a material.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

If you had two rocks that were the same size, but one rock was much heavier than the other, the heavier rock would be more dense. It is more dense because the materials that make up the rock are more closely compacted together.





If we were to weigh each of these rocks (in grams) and determine their volume (in cubic centimeters), the density would equal the number of grams each cubic centimeter of rock weighs.

Show them an example of two materials that are approximately the same size, but weigh different amounts. Some minerals are also heavier than others of the same size. For example, gold is much heavier than many other minerals.

Geologists use a property called specific gravity to determine whether one mineral is heavier than another.

Specific gravity is the number of times a mineral is as heavy as an equal volume of water. For example, gold has a specific gravity of 19.3. This means that one ounce of gold will be 19.3 times heavier than one ounce of water.

$$\text{Specific Gravity} = \frac{\text{mass (of mineral) in air}}{\text{mass in air} - \text{mass in water}}$$

Relate these properties to the process of panning for gold. Early miners used the properties of density and specific gravity to develop a method for separating gold from other materials. They knew that a piece of gold was much heavier than water and much heavier than rocks of the same size. So, they figured that by adding water to the silt, sand and rocks in their pan and sloshing the mixture around, the heavier gold would eventually work its way to the bottom of the pan. Then they had to remove the rest of the materials from the pan and look for the gold at the bottom. The principles are easy to understand, but it takes a lot of practice to get good at gold panning.

Activity I (Length: 30 minutes)

The objective of the activity is to determine the mass, volume, density and specific gravity of a variety of materials and compare these values to the properties of gold.

Note: Use enough of each material to register a measurable change in water level within the cylinder. For example, bundle several pennies together rather than using one penny.

Step 1: Mass

1. Use a balance scale to weigh each material to the nearest gram (copper pennies, lead weights, iron nails, quartz and granite).
2. Record the weight in grams on the worksheet.

Step 2: Volume

1. Fill a graduated cylinder approximately half full (deep enough to submerge the material) and record the number of millimeters of water in the cylinder.
2. Tie a string to the first material and completely submerge it into the cylinder.
3. The water should rise. Read the new volume of the cylinder in millimeters. The difference between this measurement and the original volume measurement equals the volume of space occupied by the material that was added to the cylinder.
4. Repeat for each material.
5. On the worksheet, record the number of cubic centimeters of volume occupied by each material (note that 1 millimeter = 1 cubic centimeter).

Step 3: Density
1. Calculate the density of each material using the equation above. The units will be grams per cubic centimeter.
2. Record the density on the worksheet.

Step 4: Specific Gravity
1. The information recorded in Step 1 is the mass of each material in air.
2. To determine the mass of each material in water, you will need to record the mass of the cylinder and water combined, and the mass of the cylinder, water and material combined. The difference between these two will equal the mass of the material in water.
3. Calculate the specific gravity using this information and the equation above.

Activity II (Length: 20 minutes)

Select 4 “mystery” materials that were brought in by the students. Have the students take turns handling the materials and have them try to rank the materials by density or specific gravity from lowest to highest (by visual inspection only). Then, follow the process in Activity I to accurately determine the density and specific gravity of the mystery materials. How did the measurements compare to the guesses?

Discussion (Length: 20 minutes)

Which material had the highest density? specific gravity? What does that tell you about that material? How do the specific gravity of these materials compare to the specific gravity of gold?

Set up a scenario where the class is going to mine an area by panning. If the deposit contained all of the materials that were measured in this activity, which material would be found at the bottom of the pan? Which material would rise to the top of the pan?

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.

MINING MONOPOLY

Description

Students will explore the various phases involved in the development of a mine and the economic aspects of these phases. They will gain an understanding of the decision-making processes involved in determining whether an ore body can be profitably mined.

VOCABULARY:

1. Exploration
2. Claim
3. Drilling
4. Ore body
5. Waste rock
6. Mineral valuation
7. Profit

MATERIALS:

- *Ground Rules* film
- Approximately 500 poker chips (same color)
- One color of paint (not same color as poker chips) and brushes
- Graph paper
- Colored markers (two colors to match poker chip color and paint color)
- Play money ($1,000 to each group in $5 denominations)
- Timers
- Calculators

Introduction (Length: 15 minutes)

Watch Chapter 1 “Exploration” and Chapter 2 “Modern Mining” of the *Ground Rules* film.

Discuss the stages involved in the development of a metal mine. Emphasize the decision-making processes involved in deciding whether to develop a mine.

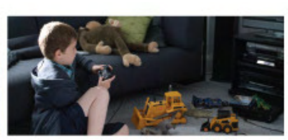
The first stage in the development of a mine is called “Mineral Exploration”. This phase involves identification of an ore body, mapping the location and extent of the ore body, staking a claim, drilling to collect core samples, analyzing the core samples for mineral content and chemistry, and determining the resource potential of the property.

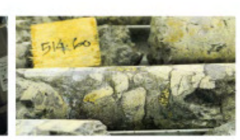
Introduce the concept of costs and benefits. In mining, there are a variety of costs, such as exploration work, regulatory processes, equipment, engineering challenges, mining labour, training, health and safety, and reclamation.

The benefits of mining arise from the value of the metals extracted. The grade or concentration of the metal as well as its form of occurrence will affect the costs associated with mining the ore. Therefore, the costs involved in extracting the ore must be weighed carefully against the value of the metal deposit to determine if the mine can be profitable. Mining companies usually conduct feasibility studies to determine the viability of potential mines.

Discuss the concept of mineral valuation. Different minerals have different values (for example, a pound of gold is worth much more than a pound of lead). The value of the





mineral is determined by the demand for that mineral to make the things that we use in our everyday lives.

Discuss the process of extracting ore. Only a portion of the ore body contains the metals of interest. During the mining process, the metals of interest are extracted from the surrounding rock. The remaining waste rock must be disposed of in an environmentally responsible manner. Typically, the volumes of waste rock are far greater than the volumes of the metal. The company has to decide where to stock pile the waste rock and how to incorporate this into the reclaimed landscape at the conclusion of the mining process.

Activity I (Length: 60 minutes + 30 minutes preparation time)

The objective of the activity is to develop a profitable mining operation. Students should work in groups for this activity because in the real world, these decisions are made by teams of people.

Student Preparation (15 minutes):

1. Divide the class into three or four groups, representing mining companies.
2. Let each group name their company and create a company sign (that will be used for staking their mining claim).
3. Using the graph paper, each group should prepare a "base map" of the room where the activity will take place. The map should show all major features like doors, windows, desks, tables, cabinets, etc.

Teacher Preparation (30 minutes):

1. Paint a spot on one side of approximately 100 to 150 poker chips. The remaining unpainted poker chips will represent waste rock.
2. While students are out of the room, put the poker chips in clusters in various locations around the room (1 or 2 more clusters than there are groups of students). Each cluster represents a property which may or may not contain a valuable ore body.
3. Place approximately 25% of the painted poker chips with the painted side up and the rest with the painted side down.
4. Add approximately three times as many unpainted poker chips to each cluster (i.e., waste rock).
5. Keep an answer sheet that indicates how many of each color of poker chips are used in each cluster.
6. Give each "company" a budget of one thousand dollars in play money to bring a mine into production.

Activity:

Prior to starting the activity, explain that the poker chips represent minerals and waste rock and that some of the painted poker chips are upside down, so the full extent of the deposit is unknown. The objective of the activity is to develop the most profitable mine. Remind the students that time costs money in the mining process, so all phases of mining must be done as quickly as possible, but with careful thinking as well!

Phase 1: Site Reconnaissance

1. Set the timer for 10 minutes.
2. Using colored markers, two representatives from each company will visit each potential "property" and record dots on their base map where the known (i.e., chips with painted side face up) and unknown (i.e., face down) poker chips are located.

This is called an exploration map. THE POKER CHIPS CANNOT BE MOVED OR TURNED OVER AT THIS TIME.
3. When mapping is completed, stop the timer and record the time used (maximum 10 minutes).
4. The teacher is the bank. Each team must pay the bank $15 for each minute used for site reconnaissance.

Phase 2: Staking the Claim:
1. Set the timer for 10 minutes.
2. During this time, each company should look over their exploration map and decide where they are going to “stake their claim” (i.e., which property they are going to mine).
3. When the timer goes off, one representative from each company will place their company sign on the property they want to claim.
4. Only one company can claim each property. The first company to place their sign on the property has the claim. If there is a tie, use a coin toss to settle it.

Phase 3: Exploration Drilling:
1. Set the timer for 10 minutes.
2. Each company must drill up to six holes on their property. Drilling consists of turning over up to 6 unknown poker chips to expose the mineral types on the underside of the poker chips. The group decides how many and which poker chips they will turn over.
3. Drilling must be completed before the timer goes off.
4. Each team must pay the bank $30 for every hole drilled, whether or not they discovered any minerals.

Phase 4: Mine Development:
1. Each company will mine their whole property by turning over each remaining unknown poker chip.
2. Record the number of mined poker chips (i.e., the total number of poker chips). This includes unpainted poker chips (i.e., waste rock) and previously face-up poker chips because it also costs money to extract these from the ground.
3. Each team must pay the bank $5 for every mined poker chip.

Phase 5: Mine Valuation:
1. Record the number of mineral poker chips and waste rock poker chips.
2. The bank must pay each company $50 for each mineral poker chip.
3. Each team must pay the bank $5 for each waste rock poker chip to cover the costs of disposal and reclamation.

Discussion (Length: 15 minutes)

Which company had the most money left? What does this mean (profit)? Discuss the reasons why this mine was more profitable. For example, higher mineral content in the ore body, lower exploration costs, etc. Discuss the decision-making processes involved in each stage of mine development. What was the most difficult decision to make?

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GROUNDRULES

MINING PROCESSES	AGE: 11 TO 13	LENGTH: 1.5 HR	CURRICULUM: earth science, graphing, mapping

OREBODY MYSTERY

Description

Students will explore the processes of core drilling and geological testing. Students will collect core samples, analyze them for mineral content and map the extent of the ore body.

VOCABULARY:

1. Exploration
2. Core sample
3. Mineral
4. Ore body
5. Waste rock
6. Grid sampling

MATERIALS:

- *Ground Rules* film
- Two colors of playdough
- 2 inch pieces of clear drinking straws
- A blunt stick (lollipop stick) that will fit inside the straw and is longer than 2 inches
- Graph paper and pencils
- Real rock core samples (optional)
- Magnifying glasses (optional)

Introduction (Length: 30 minutes)

Watch Chapter 1 “Exploration” of the *Ground Rules* film.

Discuss the stages involved in the development of a metal mine. How do geologists determine where mining should occur?

Ask the students if they know what an ore body is? Explain that an ore body is a large deposit of minerals. Geologists are looking for these deposits during the exploration phase of mining development.

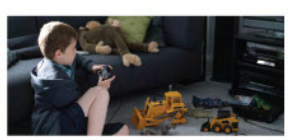
The exploration phase involves identifying an ore body, mapping the location and extent of the ore body, staking a claim, drilling to collect core samples, analyzing the core samples for mineral content and chemistry, and determining whether the property is suitable for mining.

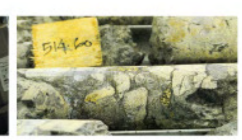
Introduce the concept of costs and benefits. In mining, there are a variety of costs, such as exploration work, regulatory processes, equipment, engineering challenges, mining labor, training, health and safety, and reclamation.

The benefits of mining arise from the value of the metals extracted. The grade or concentration of the metal as well as its form of occurrence will affect the costs associated with mining the ore. Therefore, it is important to gain an accurate understanding of the geological properties of an ore body.

Explain that drilling to collect core samples is an important step in the exploration phase of mining. During geological exploration at a potential mine site, a drilling rig would be used to drill straight down into the rock and extract cores of rock. These core samples would be analyzed for mineral content, chemistry and various other geological properties.





All of this information would assist the mining company in determining if the ore body is worth mining.

Optional: If you are able to obtain a real rock core sample, pass it around for the students to examine. You can also use magnifying glasses to have a closer look at details within the sample. Ask them to describe what they see. Is the core sample one solid color or are there bands of multiple colors? Can they see different types of minerals within the sample?

Activity (Length: 45 minutes)

The objective of this activity is to accurately map the extent of an ore body based on core sampling results.

1. Divide the class into groups of 3 to 4 students.
2. For each group, tape a piece of graph paper to the desk and have the students draw a rectangle that almost completely covers the graph paper, but leaves one or two rows of grid squares visible along the edge. The lines of the rectangle should be drawn along the graph paper grid lines. Label the horizontal edge of the rectangle with letters – one in each grid square (i.e., A,B,C,D…). Label the vertical edge of the rectangle with numbers (i.e., 1,2,3 …). Prepare two more sheets of graph paper with the exact same rectangle dimensions and labeling (one will be the answer sheet and one will be the recording sheet).
3. Give each group two colors of playdough and explain what each color of playdough represents (e.g., red represents the ore body and green represents the waste rock).
4. Have each group build an ore body on top of the graph paper within the boundaries of the rectangle. They should spread the ore body color in a random shape that does not extend to the edges of the rectangle.
5. Each group should draw the outline of their ore body on the answer sheet graph paper and give these to the teacher.
6. Next, each group will spread the waste rock color on top of the whole structure, extending to the edges of the rectangle. They should end up with a structure where they only see the waste rock color of playdough from the top and the edges. The ore body playdough color should not be visible at all.
7. The groups should switch positions so they are working on another group's ore body.
8. Within each group, students will take turns taking core samples from the ore body. Core samples are collected by pushing the straw straight down into the playdough structure, pulling it up, poking the core sample out with a stick and examining it. Use the grid squares and associated numbers and letters on the axes of the graph paper to accurately locate the position of your core samples.
9. Record core sample results on the recording sheet of graph paper. If the ore body color is visible in the core sample, record an X in the appropriate grid square on the graph paper. If no ore body color is visible, enter O in the grid square.
10. Continue sampling until your group thinks they have enough information to map out the shape of the ore body.
11. Record the number of core samples required to determine the shape of the ore body.
12. Draw an outline of the shape of the ore body on the graph paper based on the X and O pattern recorded on the graph paper. Compare this to the answer sheet.

Discussion (Length: 15 minutes)

How accurate was each group in determining the shape of their ore body? Which group had the most accurate ore body map? Which group used the least number of core samples to generate their map?

Discuss how this exercise relates to core sampling in a real ore body. Why is it important to accurately determine the shape of the ore body? Why is it important to limit the number of core samples used to determine the shape of the ore body? In addition to the shape of the ore body, what other things would you need to know about the ore body? Discuss how you could gather information from the core samples you collected to determine the volume of the ore body.

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.

Playdough Recipe

Combine 1 cup flour, ¼ cup salt, and 2 tablespoons cream of tartar with 1 cup water, 2 teaspoons food coloring and 1 tablespoon oil in a saucepan. Cook and stir 3-5 minutes, or until it sticks together in a ball. Knead for a few minutes on a lightly floured surface. Store in an air-tight container.

AGE: 11 TO 13 | LENGTH: 1 HR | CURRICULUM: mining, environment, botany, volume

RECLAIMING A MINE SITE

Description

Students will learn how overburden is stockpiled and incorporated into the landscape after closure of a mine. They will experiment with growing plants on reclaimed landscapes with various treatments. Students will test three variables: soil thickness, soil composition (layering or mixing), and nutrients.

VOCABULARY:

1. Overburden
2. Stockpile
3. Grading
4. Soil types
5. Seeding
6. Stability
7. Seed germination
8. Nutrients
9. Closure planning

MATERIALS:

- *Ground Rules* film
- Mixture of gravel, sand and silt (overburden)
- Potting soil
- Bone meal, blood meal and potash, or mixed fertilizer, teaspoons
- Grass seeds
- Water and spray bottle
- Access to sunlight or a lamp
- Small trowels
- Shoebox sized plastic tubs
- Measuring cups, large mixing bowls
- Rulers, calculators
- Data sheet (provided)

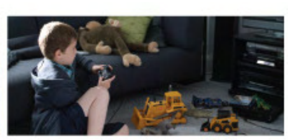
Introduction (Length: 15 minutes)

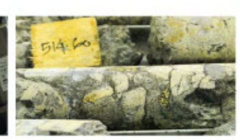
Watch Chapter 8 "Reclamation" of the *Ground Rules* film. Ask the students why mine sites have to be reclaimed after the mine has closed. Discuss the possible safety and environmental issues that could result if the mine site was not reclaimed.

Ask the students what was removed at the coal mine before they could get to the coal deposit. The top layer of soil (60 meters thick) had to be removed. This is called "overburden". Ask the students what the mining company did with the overburden. They stockpiled it on the mine site and saved it for reclamation. Emphasize the fact that reclamation has to be planned out in advance of opening the mine. This is called "Closure Planning". Mining companies have to prepare a closure plan and have it approved by the government. They also have to show that they will make enough profit during the operation of the mine to cover the costs of reclamation.

Ask the students what they noticed about the natural vegetation in the New Guinea site compared to the natural vegetation in the Wyoming site? Ask them which site they think would be easier to reclaim. Discuss the fact that the goal of reclamation is to create a landscape that is as close to the natural landscape as possible, but that this will be much harder to achieve in a mountainous, rain forest than in a flat, prairie region.





Explain that the students will be building model reclaimed landscapes and attempting to grow plants on top of them. Show the class what the overburden looks like (mixture of gravel, sand and silt). Ask them if they think plants will grow directly on top of this. Ask the students what plants need to grow – soil with nutrients, water, sunlight. Ask them how they think they can get plants to grow on top of overburden. Explain that they will be experimenting with different types of soil and nutrient mixtures to see which is the best for plant growth.

Activity (Length: 30 minutes + 5 minute daily observations)

The objective of this activity is to investigate how plants will grow on top of a reclaimed landscape under various treatments. Students will test three variables: soil thickness, soil composition (layering or mixing), and nutrients.

<u>Building a Reclaimed Landscape</u>

1. Divide the class into eight groups. Give each group a plastic tub and a garden trowel. The teacher should also have a tub and trowel.
2. Each group should label their plastic tub with their group number (1 to 8) and the teacher should label his/her tub as 9.
3. Each group should calculate the area of the bottom of their tub by multiplying the length times the width.
4. Each group will have to determine the volume of overburden required to make a 5 cm (2 inch) layer in the bottom of their tub by multiplying the area of their tub by 5 cm (2 inches). Each group should measure out the appropriate volume of overburden, then pour it into their tub and smooth it out to make an even surface of uniform thickness. They should measure the depth of the layer with a ruler in several places throughout the tub to ensure that it is uniform thickness.
5. Each group will prepare a different reclaimed landscape model with different thicknesses and mixtures of soil. Use the method in Step 4 to calculate soil volumes required to prepare various thicknesses of soil layers.
6. Each group should describe the composition of all of the reclaimed landscapes on their data sheet.

Group 1 (thin soil layer):

1. Measure out a volume of potting soil that will make a layer exactly 1 cm (1/2 inch) thick when placed on top of the overburden layer.
2. Spread the potting soil directly on top of the overburden layer being careful not to mix the two layers.

Group 2 (thin soil layer, fertilizer):

1. Measure out a volume of potting soil that will make a layer exactly 1 cm (1/2 inch) thick when placed on top of the overburden layer. Put in a mixing bowl.
2. Add 1 teaspoon each of bone meal, blood meal and potash (or 1 teaspoon of a mixed fertilizer). Mix the fertilizer thoroughly into the potting soil.
3. Spread the mixture in a layer on top of the overburden mixture being careful not to mix the two layers.

Group 3 (medium soil layer thickness):

1. Measure out a volume of potting soil that will make a layer exactly 2.5 cm (1 inch) thick when placed on top of the overburden layer.

2. Spread the potting soil directly on top of the overburden layer being careful not to mix the two layers.

Group 4 (medium soil layer thickness, fertilizer):
1. Measure out a volume of potting soil that will make a layer exactly 2.5 cm (1 inch) thick when placed on top of the overburden layer. Put in a mixing bowl.
2. Add 2 teaspoons each of bone meal, blood meal and potash (or 2 teaspoons of a mixed fertilizer). Mix the fertilizer thoroughly into the potting soil.
3. Spread the mixture in a layer on top of the overburden mixture being careful not to mix the two layers.

Group 5 (thick soil layer):
1. Measure out a volume of potting soil that will make a layer exactly 4 cm (1 ½ inches) thick when placed on top of the overburden layer.
2. Spread the potting soil directly on top of the overburden layer being careful not to mix the two layers.

Group 6 (thick soil layer, fertilizer):
1. Measure out a volume of potting soil that will make a layer exactly 4 cm (1 ½ inches) thick when placed on top of the overburden layer. Put in a mixing bowl.
2. Add 3 teaspoons each of bone meal, blood meal and potash (or 3 teaspoons of a mixed fertilizer). Mix the fertilizer thoroughly into the potting soil.
3. Spread the mixture in a layer on top of the overburden mixture being careful not to mix the two layers.

Group 7 (mixture of soil and overburden):
1. Measure out a volume of potting soil that will make a layer exactly 2.5 cm (1 inch) thick when placed on top of the overburden layer.
2. Mix the potting soil thoroughly into the overburden layer. Smooth the surface of the overburden-potting soil mixture.

Group 8 (mixture of soil and overburden, fertilizer):
1. Measure out a volume of potting soil that will make a layer exactly 2.5 cm (1 inch) thick when placed on top of the overburden layer. Put in a mixing bowl.
2. Add 2 teaspoons each of bone meal, blood meal and potash (or 2 teaspoons of a mixed fertilizer). Mix the fertilizer thoroughly into the potting soil.
3. Mix the potting soil-fertilizer mixture thoroughly into the overburden layer. Smooth the surface of the overburden-potting soil-fertilizer mixture.

<u>Adding the Plants (all groups)</u>
1. Each group and the teacher should sprinkle 4 teaspoons of grass seed as evenly as possible across the surface of their reclaimed landscape.
2. Gently pat the seeds into the surface of the soil.
3. Using the spray bottle of water, the teacher should spray a generous amount of water evenly over the surface of his/her reclaimed landscape. The total number of sprays used should be counted and recorded.
4. Each group should then spray their reclaimed landscapes with the same number of sprays.
5. Place all of the tubs near a window or under a lamp that is turned on during the day and off at night.

Daily Observations (all groups)

1. Water the model reclaimed landscapes every day using a spray bottle, making sure to apply the same number of sprays to each tub. Give them extra water on Fridays so they will have enough to get through the weekends.
2. Each group should make daily observations of all of the reclaimed landscape models on their data sheet. Continue making daily observations until the grass is growing well on at least one of the models.

Discussion (Length: 15 minutes)

What variables were kept constant in this experiment? Water, light, grass seed, overburden layer, flat terrain. What variables were tested in this experiment? (potting soil thickness, layered vs. mixing of potting soil and overburden, fertilizers (nutrients) What other variables could have been tested? (different types of seeds, sloped terrains, different amounts of fertilizers, etc.)

On which reclaimed landscape(s) did the plants grow the best/worst? On which reclaimed landscape(s) did plants grow the fastest? On which reclaimed landscape(s) did plants look the healthiest? Were the students hypotheses correct? What do plants need to grow on a reclaimed landscape? Based on the results of the experiment, if you were planning a reclaimed landscape, how would you design it?

Explain that this experiment is a simple demonstration of reclamation of a flat landscape to a grassland ecosystem. Discuss what would be required to reclaim a landscape to a forest ecosystem or to create a landscape with varied topography.

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.

Reclaim a Mine Site Data Sheet

A) Initial Observations and Hypotheses

Date: ___________

1. Describe the composition of the reclaimed landscapes

   Landscape 1:

   Landscape 2:

   Landscape 3:

   Landscape 4:

   Landscape 5:

   Landscape 6:

   Landscape 7:

   Landscape 8:

   Landscape 9:

   Which landscape is the control? Why?

2. On which landscape do you think plants will be able to grow the best? Why?

3. On which landscape(s) do you think plants will not grow at all. Why?

B) Daily Observations

Number of days until plants start to grow in at least one of the reclaimed landscapes: __________

On the first day plant growth is visible in at least one of the reclaimed landscapes, start making daily observations by filling in a table for each day. Copy the following table for each day as required until the end of the experiment.

Date: _________________

Observations	1	2	3	4	5	6	7	8	9
Growth visible? (Y/N)									
% of surface covered with plants (%)									
Height of tallest plant (mm)									
Do plants look healthy? (Y/N) Describe.									
Other observations									

GROUNDRULES

MINING PROCESSES | AGE: 11 TO 13 | LENGTH: 1.25HR | CURRICULUM: simple/complex machines, math

THE WHEELBARROW ADVANTAGE

Description

Students will explore how simple and complex machines make work easier at a mine site.

VOCABULARY:

1. Load
2. Force
3. Mechanical advantage
4. Inclined plane
5. Wedge
6. Pulley
7. Screw
8. Wheel and axle
9. Lever
10. Simple machine
11. Complex machine

MATERIALS:

- *Ground Rules* film
- Cardboard boxes (shoebox size)
- Cardboard pieces (dividers)
- Wooden dowels or long sticks
- Hot glue gun
- Spring scales
- Weights or objects to use as weights
- Assortment of building/craft materials
- Wheels and axles (optional)
- Calculators

Introduction (Length: 20 minutes)

Watch Chapter 2 “Modern Mining” of the *Ground Rules* film.

Discuss how simple and complex machines are used to help miners extract mineral from ore. A wide variety of machines are used in the mining process to help miners do their work more efficiently by decreasing the amount of effort and time required to complete tasks.

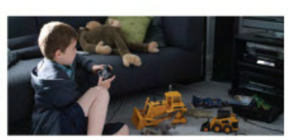
Ask students if they know the difference between a simple machine and a complex machine. Describe the six kinds of simple machines that help lift or move objects: the inclined plane, the wedge, the pulley, the screw, the wheel and axle, and the lever. These six simple machines can work alone, or they can work in combination. If two or more simple machines are put together, then you have a complex machine that makes work even easier.

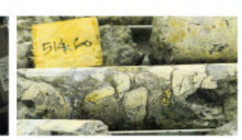
Introduce the concept of mechanical advantage. Explain that we can measure the effectiveness of a machine by calculating the mechanical advantage. The mechanical advantage can be used to determine how much easier a job has become with the help of the machine. The mechanical advantage equals the number of times a machine multiplies your effort (or force).

To calculate the mechanical advantage, divide the load by the force, as follows:

$$\text{Mechanical Advantage} = \frac{\text{Load}}{\text{Force}}$$





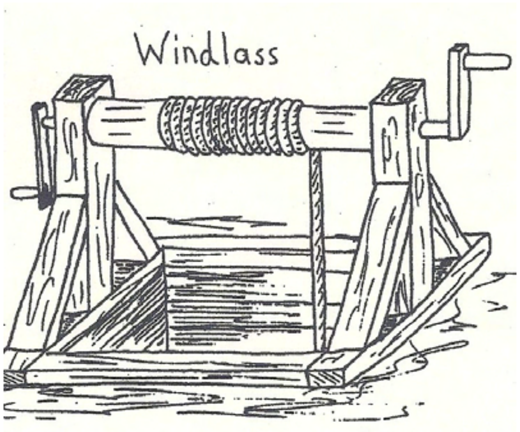
Give an example on the board: If a rock weights 100 lbs (load) and we create a simple machine that requires us to use 50 lbs of our force to lift the rock, then the mechanical advantage of our machine would be 2 (i.e., 100 / 50 = 2). In other words, the simple machine multiplied our effort by 2. It allowed us to do the work using half the effort it would have taken us to do the work without the machine.

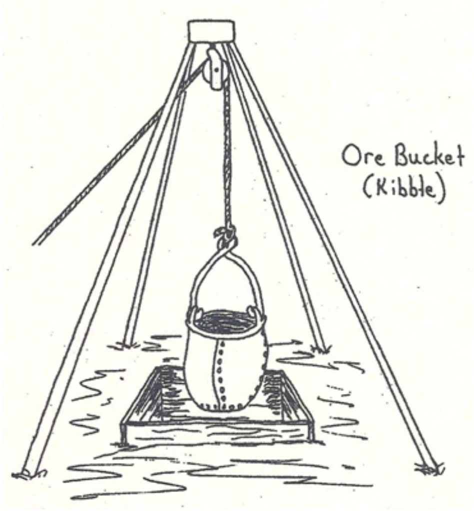
As the mechanical advantage increases, the machine becomes more efficient and less effort is expended by the miner. This allows more work to be done. Engineers can use the mechanical advantage formula to make modifications to existing machines to further enhance efficiency.

Discuss the connection between machines and mining. In the early 19^{th} Century, miners used many simple and complex machines to increase the efficiency of the mining process. Some examples of these early machines include:

- Wheelbarrow: wheel and axle, levers, screws
- Pick: lever, wedge
- Crow bar: lever, wedge
- Concentration table: inclined plane
- Windlass: lever, wheel and axle, screw
- Ore bucket: pulley, screw, wheel and axle

Today, much more complex machines are used in mining, but the basic concepts of mechanical advantage still apply.





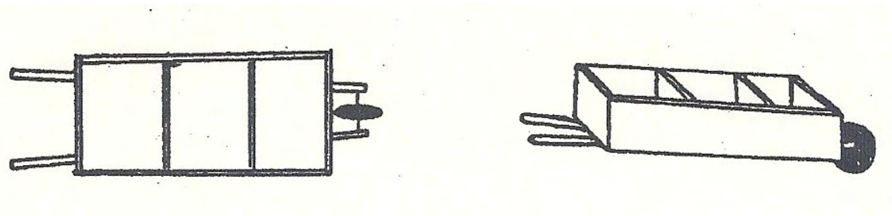
Discuss the two simple machines that make up the wheelbarrow – a lever, and a wheel and axle. The lever helps you lift the load and the wheel and axle helps you move the load. This activity will explore how the wheelbarrow uses a lever to create mechanical advantage.

Activity I (Length: 20 minutes)

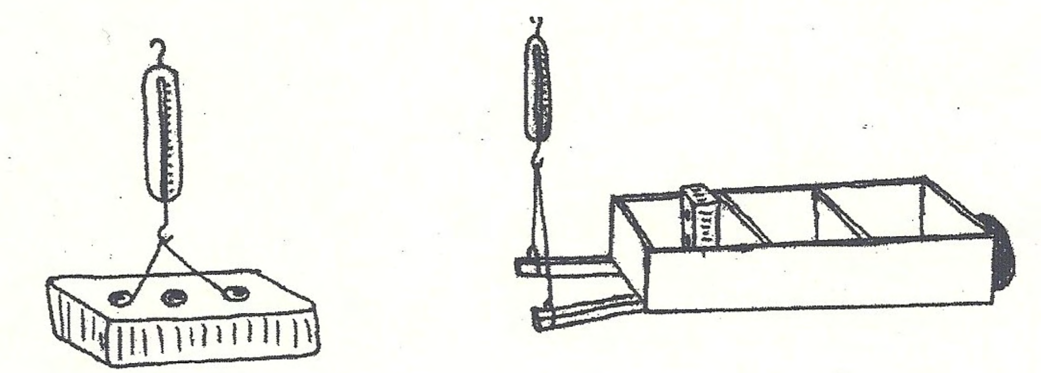
In this activity, students will build a model of a wheelbarrow and explore how load placement affects the mechanical advantage of the wheelbarrow.

Remind students that a wheelbarrow is actually a complex machine since it is made of a wheel and axle at the end of two levers. However, it is not necessary to use a wheel and axle for this activity.

1. Ask students to construct a wheelbarrow using a cardboard box and long sticks or wooden dowels. Attach extra pieces of cardboard to the inside of the box to divide it into at least 3 sections from front to back. The more sections you have the more data you will be able to collect. Glue two long sticks or wooden dowels to the underside of the box in a V-shape as shown below. The sticks should extend beyond both ends of the box. On one end, the sticks will be attached at the outside edges of the box to create the handles. At the other end, the sticks will be attached closer together to form the levers.



2. Using a spring scale, weigh the object you are using to represent the load. Next add the object to the wheelbarrow section closest to the handles. Attach a spring scale to the handles and lift to determine the force exerted to lift the load.



3. Calculate the mechanical advantage.
4. Change the location of the load to the next section and record the mechanical advantage. Repeat for every section.

Which position resulted in the greatest mechanical advantage? Why? Remember, the higher the number of the mechanical advantage, the easier it is for you to do the work. Where is the best place to put materials in the wheelbarrow?

Activity II (Length: 20 minutes)

Divide the class into groups of 2 to 4 students. Using an assortment of building/craft materials available within the classroom, ask the groups to create a wheelbarrow they believe would have the greatest mechanical advantage. Each group should calculate the mechanical advantage of their wheelbarrow.

Discussion (Length: 15 minutes)

Activity I:
How did placement of the load within the wheelbarrow affect the mechanical advantage? Which position within the wheelbarrow resulted in the highest mechanical advantage? Why? The further you are away from the load and the closer the load is to the axle, the easier it will be to lift.

Activity II:
Discuss which alterations improved mechanical advantage and which did not. Why?

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GROUNDRULES

MINING PROCESSES

Mining Processes

AGES 13-15

MASS, VOLUME, DENSITY AND SPECIFIC GRAVITY

Description

Students will determine the mass, volume, density and specific gravity of different materials and compare them to the density of gold. They will discover how these properties enabled early miners to pan for gold.

VOCABULARY:

1. Mass
2. Volume
3. Density
4. Specific gravity
5. Panning for gold

MATERIALS:

- *Ground Rules* film
- Graduated cylinder (millimeter intervals)
- Water
- String
- Balance scale with weights and calculator
- Copper pennies
- Lead fishing weights
- Iron carpenter’s nails
- Quartz and granite rocks
- Sand, pebble and silt mixture
- Small pieces of copper wire
- Shallow pie plates and waste buckets
- Rock and mineral field guide or Internet access

Introduction (Length: 20 minutes)

Watch Chapter 1 “Exploration” of the *Ground Rules* film. Focus on the section where the geologists are panning for gold in the creek.

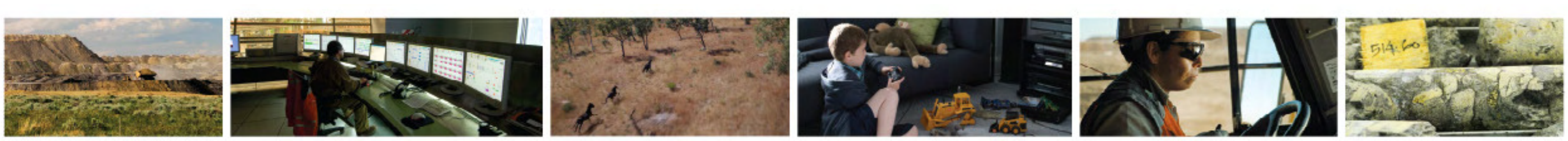
Ask the students if they have ever tried panning for gold. Do they know how it works? How do geologists separate the gold from the water and other rocks, sand and silt? The answer has to do with the properties of mass, volume, density and specific gravity.

Review the concepts of mass and volume. When we weigh a material, we are determining its mass. When we find out how much space the material occupies, we are determining its volume.

Density is the ratio between the mass and the volume of a material.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

If you had two rocks that were the same size, but one rock was much heavier than the other, the heavier rock would be more dense. It is more dense because the materials that make up the rock are more closely compacted together.



If we were to weigh each of these rocks (in grams) and determine their volume (in cubic centimeters), the density would equal the number of grams each cubic centimeter of rock weighs.

Show them an example of two materials that are approximately the same size, but weigh different amounts. Some minerals are also heavier than others of the same size. For example, gold is much heavier than many other minerals.

Geologists use a property called specific gravity to determine whether one mineral is heavier than another.

Specific gravity is the number of times a mineral is as heavy as an equal volume of water. For example, gold has a specific gravity of 19.3. This means that one ounce of gold will be 19.3 times heavier than one ounce of water.

$$\text{Specific Gravity} = \frac{\text{mass (of mineral) in air}}{\text{mass in air – mass in water}}$$

Relate these properties to the process of panning for gold. Early miners used the properties of density and specific gravity to develop a method for separating gold from other materials. They knew that a piece of gold was much heavier than water and much heavier than rocks of the same size. So, they figured that by adding water to the silt, sand and rocks in their pan and sloshing the mixture around, the heavier gold would eventually work its way to the bottom of the pan. Then they had to remove the rest of the materials from the pan and look for the gold at the bottom. The principles are easy to understand, but it takes a lot of practice to get good at gold panning.

Activity I (Length: 30 minutes)

The objective of the activity is to determine the mass, volume, density and specific gravity of a variety of materials and compare these values to the properties of gold.

Note: Use enough of each material to register a measurable change in water level within the cylinder. For example, bundle several pennies together rather than using one penny.

<u>Step 1: Mass</u>

1. Use a balance scale to weigh each material to the nearest gram (copper pennies, lead weights, iron nails, quartz and granite).
2. Record the weight in grams on the worksheet.

<u>Step 2: Volume</u>

1. Fill a graduated cylinder approximately half full (deep enough to submerge the material) and record the number of millimeters of water in the cylinder.
2. Tie a string to the first material and completely submerge it into the cylinder.
3. The water should rise. Read the new volume of the cylinder in millimeters. The difference between this measurement and the original volume measurement equals the volume of space occupied by the material that was added to the cylinder.
4. Repeat for each material.
5. On the worksheet, record the number of cubic centimeters of volume occupied by each material (note that 1 millimeter = 1 cubic centimeter).

Step 3: Density
1. Calculate the density of each material using the equation above. The units will be grams per cubic centimeter.
2. Record the density on the worksheet.

Step 4: Specific Gravity
1. The information recorded in Step 1 is the mass of each material in air.
2. To determine the mass of each material in water, you will need to record the mass of the cylinder and water combined, and the mass of the cylinder, water and material combined. The difference between these two will equal the mass of the material in water.
3. Calculate the specific gravity using this information and the equation above.

Activity II (Length: 20 minutes)

The objective of this activity is to experience what it is like to pan for gold.

1. Create a few small "copper nuggets" by braiding together a few pieces of copper wire. Make sure the edges are tucked in so they are not sharp. Dull copper pennies can be used instead of wire if desired, but the wire is harder to find.
2. Mix together some sand, silt and pebbles. Add a small quantity of "copper nuggets" and mix well.
3. Scoop approximately 1 cup of this mixture into a shallow pie plate. Add enough water to fill the pan approximately 2/3 full.
4. Position the pie plate over the waste bucket.
5. Swirl the mixture around to separate the fine particles and settle the larger particles to the bottom of the pan.
6. As the lighter particles come to the surface, pour them off into the bucket.
7. Add more water and mix the solution over and over, as needed until most of the mixture has been removed and there is only a small amount left on the bottom of the pan.
8. Carefully drain the remaining water without disturbing the sediments that have collected in the bottom of the pan.
9. Locate the copper wire (and/or pennies) in the pan.

Discussion (Length: 20 minutes)

Activity I:
Which material had the highest density? specific gravity? What does that tell you about that material? How do the specific gravity of these materials compare to the specific gravity of gold?

Activity II:
Which size of particles were you able to get rid of first? Why did the copper nuggets settle to the bottom of the pan? Look up the specific gravity of copper in a rock and mineral field guide or on the Internet. Compare the specific gravity of copper to the other minerals present in the sand, silt and quartz and granite pebbles.

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THE MINING PROCESS GAME

Description

Students will explore the various phases involved in the development of a mine and the economic aspects of these phases. They will gain an understanding of the decision-making processes involved in determining whether an ore body can be profitably mined.

VOCABULARY:

1. Exploration
2. Claim
3. Drilling
4. Ore body
5. Waste rock
6. Mineral valuation
7. Gross and Net Profit

MATERIALS:

- *Ground Rules* film
- Approximately 500 poker chips (same color)
- Two colors of paint (not same color as poker chips) and brushes
- Graph paper
- Colored markers (three colors to match poker chip color and paint colors)
- Worksheet (included in lesson plan)
- Timers
- Calculators

Introduction (Length: 30 minutes)

Watch Chapter 1 “Exploration” and Chapter 2 “Modern Mining” of *Ground Rules*.

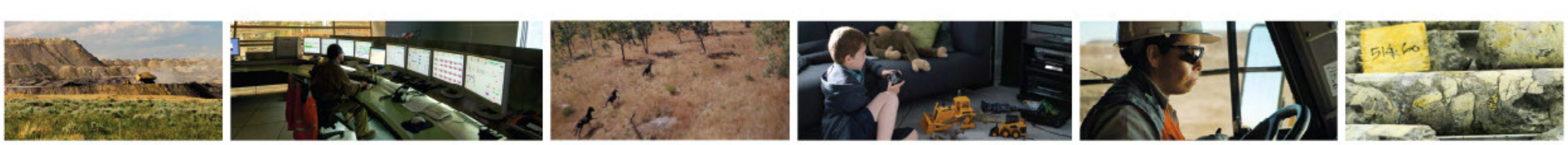
Discuss the stages involved in the development of a metal mine. Emphasize the decision-making processes involved in deciding whether to develop a mine.

The first stage in the development of a mine is called “Mineral Exploration”. This phase involves identification of an ore body, mapping the location and extent of the ore body, staking a claim, drilling to collect core samples, analyzing the core samples for mineral content and chemistry, and determining the resource potential of the property.

Introduce the concept of costs and benefits. In mining, there are a variety of costs, such as exploration work, regulatory processes, equipment, engineering challenges, mining labour, training, health and safety, and reclamation.

The benefits of mining arise from the value of the metals extracted. The grade or concentration of the metal as well as its form of occurrence will affect the costs associated with mining the ore. Therefore, the costs involved in extracting the ore must be weighed carefully against the value of the metal deposit to determine if the mine can be profitable. Mining companies usually conduct feasibility studies to determine the viability of potential mines.

Discuss the concept of mineral valuation. Different minerals have different values (for example, a pound of gold is worth much more than a pound of lead). The value of the mineral is determined by the demand for that mineral to make the things that we use in our everyday lives.



Discuss the process of extracting ore. Only a portion of the ore body contains the metals of interest. During the mining process, the metals of interest are extracted from the surrounding rock. The remaining waste rock must be disposed of in an environmentally responsible manner. Typically, the volumes of waste rock are far greater than the volumes of the metal. The company has to decide where to stock pile the waste rock and how to incorporate this into the reclaimed landscape at the conclusion of the mining process.

Activity (Length: 60 minutes + 30 minutes preparation time)

The objective of the activity is to develop a profitable mining operation. Students should work in groups for this activity because in the real world, these decisions are made by teams of people.

Student Preparation (15 minutes):

1. Divide the class into three or four groups, representing mining companies.
2. Let each group name their company and create a company sign (that will be used for staking their mining claim).
3. Using the graph paper, each group should prepare a "base map" of the room where the activity will take place. The map should show all major features like doors, windows, desks, tables, cabinets, etc. To increase mapping precision, the map may be drawn to scale and compass direction, although this is not essential to the activity.

Teacher Preparation (30 minutes):

1. Assign the two paint colors to two mineral types. For example: yellow = gold, green = copper.
2. Paint a spot of one color on one side of approximately 50 to 75 poker chips. Paint a spot of the other color on one side of another 50 to 75 poker chips. The remaining unpainted poker chips will represent waste rock.
3. While students are out of the room, put the poker chips in clusters in various locations around the room (1 or 2 more clusters than there are groups of students). Each cluster represents a property which may or may not contain a valuable ore body. You can group the two colors together to represent the ore bodies because several different minerals are often found together in nature (but each property should have one dominant mineral type and less of the secondary mineral; make sure the deposits differ from one another).
4. Place approximately 25% of the painted poker chips with the painted side up and the rest with the painted side down.
5. Add approximately three times as many unpainted poker chips to each cluster (i.e., waste rock).
6. Keep an answer sheet that indicates how many of each color of poker chips are used in each cluster.
7. Provide the following information to each company:
    a. A set of colored markers (matching the paint colors and poker chip color).
    b. A list of the poker chip colors and their corresponding mineral type. Students should add a legend to their map indicating which colors represent which mineral types (using the colored markers).
    c. The value of 1 poker chip of each mineral type (use dollar amounts for gold and copper in mine valuation section of the worksheet or similar values reflective of the relative value of these or other mineral types in the real world).

Activity:

Prior to starting the activity, explain that the poker chips represent minerals and waste rock and that some of the painted poker chips are upside down, so the full extent of the deposit is unknown. The objective of the activity is to develop the most profitable mine. Remind the students that time costs money in the mining process, so all phases of mining must be done as quickly as possible, but with careful thinking as well!

<u>Phase 1: Site Reconnaissance</u>

1. Set the timer for 10 minutes.
2. Using colored markers, two representatives from each company will visit each potential “property” and record dots on their base map where the known (i.e., chips with painted side face up) and unknown (i.e., face down) poker chips are located. This is called an exploration map. THE POKER CHIPS CANNOT BE MOVED OR TURNED OVER AT THIS TIME.
3. When mapping is completed, stop the timer.
4. Each company must record on their worksheet the number of minutes used in the exploration phase and calculate the cost of exploration on their worksheet.

<u>Phase 2: Staking the Claim:</u>

1. Set the timer for 10 minutes.
2. During this time, each company should look over their exploration map and decide where they are going to “stake their claim” (i.e., which property they are going to mine).
3. When the timer goes off, one representative from each company will place their company sign on the property they want to claim.
4. Only one company can claim each property. The first company to place their sign on the property has the claim. If there is a tie, use a coin toss to settle it.

<u>Phase 3: Exploration Drilling:</u>

1. Set the timer for 10 minutes.
2. Each company must drill up to six holes on their property. Drilling consists of turning over up to 6 unknown poker chips to expose the mineral types on the underside of the poker chips. The group decides how many and which poker chips they will turn over.
3. Drilling must be completed before the timer goes off.
4. Calculate the cost of drilling on the worksheet.

<u>Phase 4: Mine Development</u>:

1. Each company will mine their whole property by turning over each remaining unknown poker chip.
2. Record the number of mined poker chips (i.e., the total number of poker chips). This includes unpainted poker chips (i.e., waste rock) and previously face-up poker chips because it also costs money to extract these from the ground.
3. Calculate the cost of mine development on the worksheet.

<u>Phase 5: Mine Valuation:</u>

1. Record the number of poker chips of each mineral type on the worksheet and calculate the value of each mineral type.
2. Record the number of waste rock poker chips on the worksheet and calculate the waste disposal costs.

Phase 6: Calculate Mine Profit:
1. Fill in the cost-benefit table on the worksheet.
2. Calculate the total costs, total benefits and gross profit.
3. Calculate reclamation costs and net profit.

Discussion (Length: 15 minutes)

Which company had the most profitable mine? Discuss the reasons why this mine was more profitable. For example, it had more gold ore in it than copper, exploration costs were minimized, etc. Discuss the decision-making processes involved in each stage of mine development. What was the most difficult decision to make?

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.

Worksheet

Company Name ________________________________ Date __________________

Phase 1: Site Reconnnaissance

Field/Mapping costs: $15,000 per minute (maximum 10 minutes)

__________ minutes x $15,000/minute = $ ___________________

Phase 3: Exploration Drilling

Drilling costs: $30,000 per poker chip (maximum of 6 per site)

__________ poker chips x $30,000/chip = $ ________________

Phase 4: Mine Development

Mining costs: $5,000 per poker chip

__________ poker chips x $5,000/chip = $ _________________

Phase 5: Mine Valuation

<u>Mineral Revenue</u>:

Gold: _________ poker chips x $400,000 = $ ______________

Copper: _________ poker chips x $20,000 = $ ______________

Total Mineral Revenue (Sum) = $ ______________

<u>Waste Rock Disposal Costs</u>:

_________ poker chips x $2,000 = $ ______________

Phase 6: Calculate Mine Profit

MINING PHASE	AMOUNT
Benefits	
Total Mineral Revenue	$
TOTAL PROJECT BENEFITS	**$**
Costs	
Site Reconnaissance	$
Drilling	$
Mining	$
Waste rock disposal	$
TOTAL PROJECT COSTS	**$**
GROSS PROFIT (project benefits – project costs)	**$**
Reclamation costs (10% of gross profits)	$
NET PROFIT (gross profit – reclamation costs)	**$**

OREBODY MYSTERY

Description

Students will explore the processes of core drilling and geological testing. Students will collect core samples, analyze them for mineral content, map the extent of the ore body and determine its approximate area and volume.

VOCABULARY:

1. Exploration
2. Core sample
3. Mineral
4. Ore body
5. Waste rock
6. Grid sampling

MATERIALS:

- *Ground Rules* film
- Two colors of playdough
- 2 inch pieces of clear drinking straws
- A blunt stick (lollipop stick) that will fit inside the straw and is longer than 2 inches
- Graph paper and pencils
- Calculators
- Rulers
- Real rock core samples (optional)
- Magnifying glasses (optional)

Introduction (Length: 30 minutes)

Watch Chapter 1 “Exploration” of *Ground Rules* film.

Discuss the stages involved in the development of a metal mine. How do geologists determine where mining should occur?

Ask the students if they know what an ore body is? Explain that an ore body is a large deposit of minerals. Geologists are looking for these deposits during the “exploration” stage of mining development.

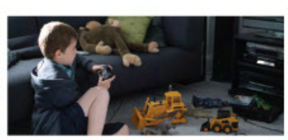
The exploration phase involves identifying an ore body, mapping the location and extent of the ore body, staking a claim, drilling to collect core samples, analyzing the core samples for mineral content and chemistry, and determining whether the property is suitable for mining.

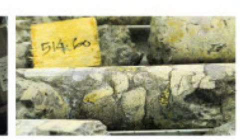
Introduce the concept of costs and benefits. In mining, there are a variety of costs, such as exploration work, regulatory processes, equipment, engineering challenges, mining labor, training, health and safety, and reclamation.

The benefits of mining arise from the value of the metals extracted. The grade or concentration of the metal as well as its form of occurrence will affect the costs associated with mining the ore. Therefore, it is important to gain an accurate understanding of the geological properties of an ore body.

Explain that drilling to collect core samples is an important step in the exploration phase of mining. During geological exploration at a potential mine site, a drilling rig would be





used to drill into the rock and extract cores of rock. These core samples would be analyzed for mineral content, chemistry and various other geological variables. All of this information would assist the mining company in determining if the ore body is rich enough to support a profitable mine.

Optional: If you are able to obtain a real rock core sample, pass it around for the students to examine. You can also use magnifying glasses to have a closer look at details within the sample. Ask them to describe what they see. Is the core sample one solid color or are there bands of multiple colors? Can they see different types of minerals within the sample?

Activity (Length: 45 minutes)

The objective of the activity is to accurately map the extent of an ore body and determine its volume based on core sampling results.

1. Divide the class into groups of 3 to 4 students.
2. For each group, tape a piece of graph paper to the desk and have the students draw a rectangle that almost completely covers the graph paper, but leaves one or two rows of grid squares visible along the edge. The lines of the rectangle should be drawn along the graph paper grid lines. Label the horizontal edge of the rectangle with letters – one in each grid square (i.e., A,B,C,D…). Label the vertical edge of the rectangle with numbers (i.e., 1,2,3 …). Prepare two more sheets of graph paper with the exact same rectangle dimensions and labeling (one will be the answer sheet and one will be the recording sheet).
3. Give each group two colors of playdough and explain what each color of playdough represents (e.g., red represents the ore body and green represents the waste rock).
4. Have each group build an ore body on top of the graph paper within the boundaries of the rectangle. They should spread the ore body color over part of the base rock layer in a random shape that does not extend to the edges of the rectangle.
5. Each group should prepare a map of their ore body on the answer sheet graph paper and give these to the teacher.
6. Next, each group will spread the waste rock color on top of the whole structure, extending to the edges of the rectangle. They should end up with a structure where they only see the waste rock color of playdough from the top and the edges. The ore body playdough color should not be visible at all.
7. The groups should switch positions so they are working on another group's ore body.
8. Within each group, students will take turns taking core samples from the ore body. Core samples are collected by pushing the straw straight down into the playdough structure, pulling it up, poking the core sample out with a stick and examining it. Use the grid squares and associated numbers and letters on the axes of the graph paper to accurately locate the position of your core samples.
9. Record core sample results on the recording sheet of graph paper. If no ore body color is visible, enter O in the grid square.
10. If the ore body color is visible, measure the depth of the ore body using a ruler. Pick a consistent unit of measurement (e.g., millimeters) and record the depth measurement number in the grid square.
11. Continue sampling until your group thinks they have enough information to map out the shape of the ore body and determine its approximate volume.
12. Record the number of core samples taken.
13. Draw an outline of the shape of the ore body on the recording sheet of graph paper and compare to the answer sheet.

14. Count up the number of full and partial grid squares occupied by the ore body to calculate the area of the ore body. Count each partial grid square as one-half of a square.
15. Determine the approximate volume of the ore body using an average of the depth measurements recorded from the core samples.

Discussion (Length: 15 minutes)

How accurate was each group in determining the shape of their ore body? Which group had the most accurate ore body map? Which group used the least number of core samples to generate their map? Use the area and volume calculations for each ore body to determine which property would be the best to develop into a mine.

Discuss how this exercise relates to core sampling in a real ore body. Why is it important to accurately determine the shape of the ore body? Why is it important to limit the number of core samples used to determine the shape of the ore body?

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.

Playdough Recipe

Combine 1 cup flour, ¼ cup salt, and 2 tablespoons cream of tartar with 1 cup water, 2 teaspoons food coloring and 1 tablespoon oil in a saucepan. Cook and stir 3-5 minutes, or until it sticks together in a ball. Knead for a few minutes on a lightly floured surface. Store in an air-tight container.

GROUNDRULES

MINING PROCESSES | AGE: 13 TO 15 | LENGTH: 1 HR | CURRICULUM: mining, environment, botany, volume

RECLAIMING A MINE SITE

Description

Students will learn how overburden is stockpiled and incorporated into the landscape after closure of a mine. They will experiment with growing plants on reclaimed landscapes with various treatments. Students will test four variables: soil thickness, soil composition (layering or mixing), slope, and nutrients.

VOCABULARY:

1. Overburden
2. Stockpile
3. Grading
4. Soil types
5. Seeding
6. Slope
7. Seed germination
8. Nutrients
9. Closure planning
10. Erosion

MATERIALS:

- *Ground Rules* film
- Mixture of gravel, sand and silt (overburden)
- Potting soil
- Bone meal, blood meal and potash, or mixed fertilizer, teaspoons
- Grass seeds
- Water and spray bottle
- Access to sunlight or a lamp
- Shoebox sized plastic tubs, small trowels
- Measuring cups, large mixing bowls
- Rulers, calculators
- Toothpicks, landscape fabric
- Data sheet (provided)

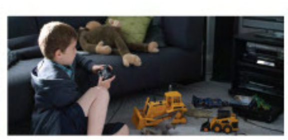
Introduction (Length: 15 minutes)

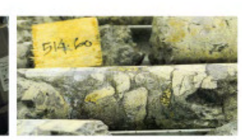
Watch Chapter 8 “Reclamation” of the *Ground Rules* film. Ask the students why mine sites have to be reclaimed after the mine has closed. Discuss the possible safety and environmental issues that could result if the mine site was not reclaimed.

Ask the students what was removed at the coal mine before they could get to the coal deposit. The top layer of soil (60 meters thick) had to be removed. This is called “overburden”. Ask the students what the mining company did with the overburden. They stockpiled it on the mine site and saved it for reclamation. Emphasize the fact that reclamation has to be planned out in advance of opening the mine. This is called “Closure Planning”. Mining companies have to prepare a closure plan and have it approved by the government. They also have to show that they will make enough profit during the operation of the mine to cover the costs of reclamation.

Ask the students what they noticed about the natural vegetation in the New Guinea site compared to the natural vegetation in the Wyoming site? Ask them which site they think would be easier to reclaim. Discuss the fact that the goal of reclamation is to create a landscape that is as close to the natural landscape as possible, but that this will be much harder to achieve in a rain forest than in a prairie region.





Explain that the students will be building model reclaimed landscapes and attempting to grow plants on top of them. Show the class what the overburden looks like (mixture of gravel, sand and silt). Ask them if they think plants will grow directly on top of this. Ask the students what plants need to grow – soil with nutrients, water, sunlight. Ask them how they think they can get plants to grow on top of overburden. Explain that they will be experimenting with different types of soil and nutrient mixtures to see which is the best for plant growth.

Activity (Length: 30 minutes + 5 minute daily observations)

The objective of this activity is to investigate how plants will grow on top of a reclaimed landscape with various treatments. Students will test four variables: soil thickness, soil composition (layering or mixing), slope, and nutrients.

<u>Building a Reclaimed Landscape</u>

1. Divide the class into eight groups. Give each group a plastic tub and a garden trowel. The teacher should also have a tub and trowel.
2. Each group should label their plastic tub with their group number (1 to 8) and the teacher should label his/her tub as 9.
3. Each group should calculate the area of the bottom of their tub by multiplying the length times the width.
4. Each group will have to determine the volume of overburden required to make a 5 cm (2 inch) layer in the bottom of their tub by multiplying the area of their tub by 5 cm (2 inches). Each group should measure out the appropriate volume of overburden.
5. Each group will prepare a different reclaimed landscape model with different thicknesses and mixtures of soil. Use the method in Step 4 to calculate soil volumes required to prepare various thicknesses of soil layers.
6. Each group should describe the composition of all of the reclaimed landscapes on their data sheet.

Group 1 (flat landscape, thin soil layer):

1. Pour the measured overburden into the bottom of the plastic tub and smooth it out to make an even surface of uniform thickness. Measure the depth of the layer with a ruler in several places throughout the tub to ensure that it is uniform thickness.
2. Measure out a volume of potting soil that will make a layer exactly 1 cm (1/2 inch) thick when placed on top of the overburden layer.
3. Spread the potting soil directly on top of the overburden layer being careful not to mix the two layers.

Group 2 (flat landscape, thin soil layer, fertilizer):

1. Pour the measured overburden into the bottom of the plastic tub and smooth it out to make an even surface of uniform thickness. Measure the depth of the layer with a ruler in several places throughout the tub to ensure that it is uniform thickness.
2. Measure out a volume of potting soil that will make a layer exactly 1 cm (1/2 inch) thick when placed on top of the overburden layer. Put in a mixing bowl.
3. Add 1 teaspoon each of bone meal, blood meal and potash (or 1 teaspoon of a mixed fertilizer). Mix the fertilizer thoroughly into the potting soil.
4. Spread the mixture in a layer on top of the overburden mixture being careful not to mix the two layers.

Group 3 (flat landscape, thick soil layer):

1. Pour the measured overburden into the bottom of the plastic tub and smooth it out to make an even surface of uniform thickness. Measure the depth of the layer with a ruler in several places throughout the tub to ensure that it is uniform thickness.

2. Measure out a volume of potting soil that will make a layer exactly 4 cm (1 ½ inches) thick when placed on top of the overburden layer.
3. Spread the potting soil directly on top of the overburden layer being careful not to mix the two layers.

Group 4 (flat landscape, thick soil layer, fertilizer):
1. Pour the measured overburden into the bottom of the plastic tub and smooth it out to make an even surface of uniform thickness. Measure the depth of the layer with a ruler in several places throughout the tub to ensure that it is uniform thickness.
2. Measure out a volume of potting soil that will make a layer exactly 4 cm (1 ½ inches) thick when placed on top of the overburden layer. Put in a mixing bowl.
3. Add 3 teaspoons each of bone meal, blood meal and potash (or 3 teaspoons of a mixed fertilizer). Mix the fertilizer thoroughly into the potting soil.
4. Spread the mixture in a layer on top of the overburden mixture being careful not to mix the two layers.

Group 5 (flat landscape, mixed overburden and soil):
1. Put the measured overburden in a mixing bowl.
2. Measure out a volume of potting soil that will make a layer exactly 2.5 cm (1 inch) thick when placed on top of the overburden layer. Add to the mixing bowl.
3. Mix the potting soil and overburden thoroughly. Pour into the plastic tub. Smooth the surface. Measure the depth of the layer with a ruler in several places throughout the tub to ensure that it is uniform thickness.

Group 6 (flat landscape, mixed overburden and soil, fertilizer):
1. Put the measured overburden in a mixing bowl.
2. Measure out a volume of potting soil that will make a layer exactly 2.5 cm (1 inch) thick when placed on top of the overburden layer. Put in a mixing bowl.
3. Add 2 teaspoons each of bone meal, blood meal and potash (or 2 teaspoons of a mixed fertilizer).
4. Mix the potting soil-fertilizer-overburden mixture thoroughly. Pour into the plastic tub. Smooth the surface. Measure the depth of the layer with a ruler in several places throughout the tub to ensure that it is uniform thickness.

Group 7 (sloped landscape):
1. Pour the measured overburden into the bottom of the plastic tub and smooth it out into a smooth, inclined slope with an angle of 45º.
2. Measure out a volume of potting soil that will make a layer exactly 1 cm (1/2 inch) thick (if it was lying horizontal in the tub).
3. Spread the potting soil evenly over the surface of the overburden layer being careful not to mix the two layers and to maintain the 45º slope.
4. If potting soil tends to slide downhill, add toothpicks and strips of landscape fabric in two rows perpendicular to the slope.

Group 8 (sloped landscape, fertilizer):
1. Pour the measured overburden into the bottom of the plastic tub and smooth it out into a smooth, inclined slope with an angle of 45º.
2. Measure out a volume of potting soil that will make a layer exactly 1 cm (1/2 inch) thick (if it was lying horizontal in the tub). Put into a mixing bowl.
3. Add 1 teaspoon each of bone meal, blood meal and potash (or 1 teaspoon of a mixed fertilizer). Mix the fertilizer thoroughly into the potting soil.
4. Spread the potting soil-fertilizer evenly over the surface of the overburden layer being careful not to mix the two layers and to maintain the 45º slope.

5. If potting soil tends to slide downhill, add toothpicks and strips of landscape fabric in two rows perpendicular to the slope.

Adding the Plants (all groups)

1. Each group and the teacher should sprinkle 4 teaspoons of grass seed as evenly as possible across the surface of their reclaimed landscape.
2. Gently pat the seeds into the surface of the soil.
3. Using the spray bottle of water, the teacher should spray a generous amount of water evenly over the surface of his/her reclaimed landscape. The total number of sprays used should be counted and recorded.
4. Each group should then spray their reclaimed landscapes with the same number of sprays.
5. Place all of the tubs near a window or under a lamp that is turned on during the day and off at night.

Daily Observations (all groups)

1. Water the model reclaimed landscapes every day using a spray bottle, making sure to apply the same number of sprays to each tub. Give them extra water on Fridays so they will have enough to get through the weekends.
2. Each group should make daily observations of all of the reclaimed landscape models on their data sheet. Continue making daily observations until the grass is growing well on at least one of the models.

Discussion (Length: 15 minutes)

What variables were kept constant in this experiment? Water, light, grass seed, overburden layer volume. What variables were tested in this experiment? Potting soil thickness, layered vs. mixing of potting soil and overburden, slope, and nutrients. What other variables could have been tested? Different types of seeds, different amounts of fertilizers, different slope angles, etc.

On which reclaimed landscape(s) did the plants grow the best/worst? On which reclaimed landscape(s) did plants grow the fastest? On which reclaimed landscape(s) did plants look the healthiest? Were the students hypotheses correct? What do plants need to grow on a reclaimed landscape? Based on the results of the experiment, if you were planning a reclaimed landscape, how would you design it?

Did the potting soil layer in the sloped landscapes stay in place throughout the experiment? Discuss erosion and the challenges this presents when reclaiming sloped landscapes.

Explain that this experiment is a simple demonstration of reclamation of a flat or sloped landscape to a grassland ecosystem. Discuss what would be required to reclaim a landscape to a forest ecosystem.

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.

Reclaim a Mine Site Data Sheet

A) Initial Observations and Hypotheses

Date: ___________

1. Describe the composition of the reclaimed landscapes

    Landscape 1:

    Landscape 2:

    Landscape 3:

    Landscape 4:

    Landscape 5:

    Landscape 6:

    Landscape 7:

    Landscape 8:

    Landscape 9:

    Which landscape is the control? Why?

2. On which landscape do you think plants will be able to grow the best? Why?

3. On which landscape(s) do you think plants will not grow at all. Why?

4. What do think will be the challenges involved in growing plants on a sloped surface compared to a flat surface?

B) Daily Observations

Number of days until plants start to grow in at least one of the reclaimed landscapes: __________

On the first day plant growth is visible in at least one of the reclaimed landscapes, start making daily observations by filling in a table for each day. Copy the following table for each day as required until the end of the experiment.

Date: _________________

Observations	1	2	3	4	5	6	7	8	9
Growth visible? (Y/N)									
% of surface covered with plants (%)									
Height of tallest plant (mm)									
Do plants look healthy? (Y/N) Describe.									
Other observations									

GROUNDRULES

MINING PROCESSES	AGE: 13 TO 15	LENGTH: 1 HR	CURRICULUM: simple/complex machines, math

THE WHEELBARROW ADVANTAGE

Description

Students will explore how simple and complex machines make work easier at a mine site.

VOCABULARY:

1. Load
2. Force
3. Mechanical advantage
4. Inclined plane
5. Wedge
6. Pulley
7. Screw
8. Wheel and axle
9. Lever
10. Simple machine
11. Complex machine
12. Torque
13. Radius

MATERIALS:

- *Ground Rules* film
- Cardboard boxes (shoebox size)
- Cardboard pieces (dividers)
- Wooden dowels or long sticks
- Hot glue gun
- Spring scales
- Weights or objects to use as weights
- Wheels and axles (different size wheels)
- Rulers
- Calculators

Introduction (Length: 20 minutes)

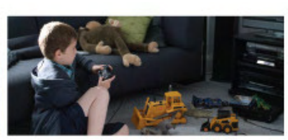
Watch Chapter 2 “Modern Mining” of the *Ground Rules* film.

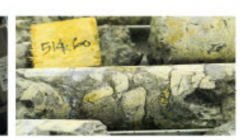
Discuss how simple and complex machines are used to help miners extract mineral from ore. A wide variety of machines are used in the mining process to help miners do their work more efficiently by decreasing the amount of effort and time required to complete tasks.

Ask students if they know the difference between a simple machine and a complex machine. Describe the six kinds of simple machines that help lift or move objects: the inclined plane, the wedge, the pulley, the screw, the wheel and axle, and the lever. These six simple machines can work alone, or they can work in combination. If two or more simple machines are put together, then you have a complex machine that makes work even easier.

Introduce the concept of mechanical advantage. Explain that we can measure the effectiveness of a machine by calculating the mechanical advantage. The mechanical advantage can be used to determine how much easier a job has become with the help of the machine. The mechanical advantage equals the number of times a machine multiplies your effort (or force).





To calculate the mechanical advantage, divide the load by the force, as follows:

$$\text{Mechanical Advantage} = \frac{\text{Load}}{\text{Force}}$$

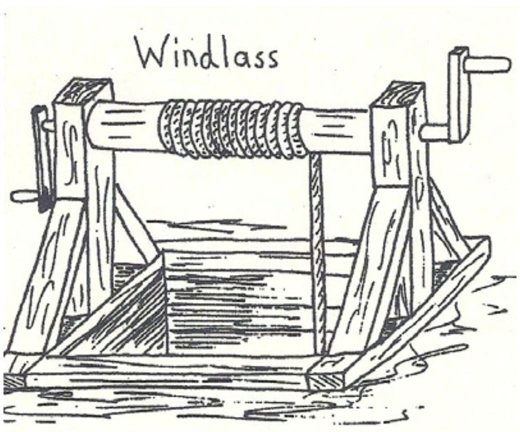
Give an example on the board: If a rock weights 100 lbs (load) and we create a simple machine that requires us to use 50 lbs of our force to lift the rock, then the mechanical advantage of our machine would be 2 (i.e., 100 / 50 = 2). In other words, the simple machine multiplied our effort by 2. It allowed us to do the work using half the effort it would have taken us to do the work without the machine.

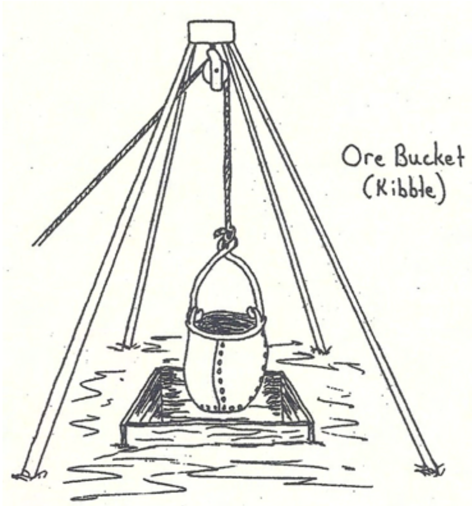
As the mechanical advantage increases, the machine becomes more efficient and less effort is expended by the miner. This allows more work to be done. Engineers can use the mechanical advantage formula to make modifications to existing machines to further enhance efficiency.

Discuss the connection between machines and mining. In the early 19th Century, miners used many simple and complex machines to increase the efficiency of the mining process. Some examples of these early machines include:

- Wheelbarrow: wheel and axle, levers, screws
- Pick: lever, wedge
- Crow bar: lever, wedge
- Concentration table: inclined plane
- Windlass: lever, wheel and axle, screw
- Ore bucket: pulley, screw, wheel and axle

Today, much more complex machines are used in mining, but the basic concepts of mechanical advantage still apply.



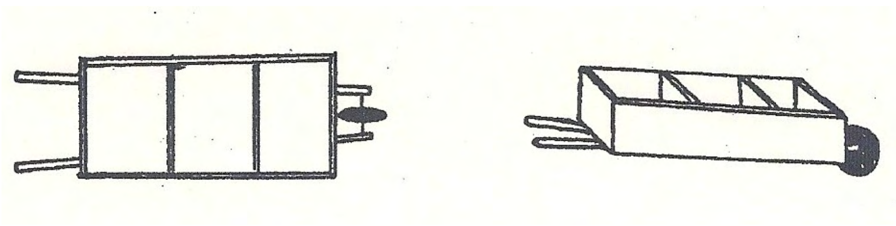


Discuss the two simple machines that make up the wheelbarrow – a lever, and a wheel and axle. The lever helps you lift the load and the wheel and axle helps you move the load. This activity will explore how these two simple machines create mechanical advantage in the wheelbarrow.

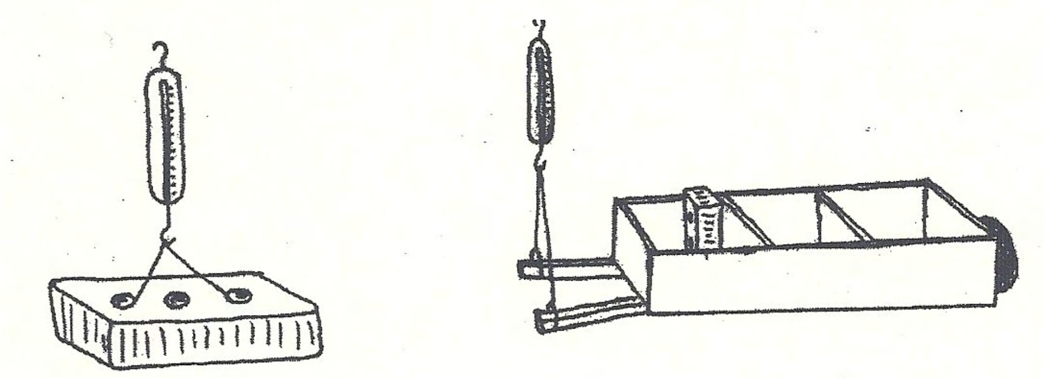
Activity I (Length: 20 minutes)

In this activity, students will build a model of a wheelbarrow and explore how load placement affects the mechanical advantage of the wheelbarrow. This activity focuses on the lever portion of the wheelbarrow.

1. Ask students to construct a wheelbarrow using a cardboard box and long sticks or wooden dowels. Attach extra pieces of cardboard to the inside of the box to divide it into at least 3 sections from front to back. The more sections you have the more data you will be able to collect. Glue two long sticks or wooden dowels to the underside of the box in a V-shape as shown below. The sticks should extend beyond both ends of the box. On one end, the sticks will be attached at the outside edges of the box to create the handles. At the other end, the sticks will be attached closer together to form the levers.



2. Using a spring scale, weigh the object you are using to represent the load. Next add the object to the wheelbarrow section closest to the handles. Attach a spring scale to the handles and lift to determine the force exerted to lift the load.



3. Calculate the mechanical advantage.
4. Change the location of the load to the next section and record the mechanical advantage. Repeat for every section.

Which position resulted in the greatest mechanical advantage? Why? Remember, the higher the number of the mechanical advantage, the easier it is for you to do the work. Where is the best place to put materials in the wheelbarrow?

Activity II (Length: 10 minutes)

The objective of this activity is to explore the mechanical advantage supplied by the wheel and axle portion of the wheelbarrow.

1. Add the smallest wheel and axle to your wheelbarrow. Put some weights in the wheelbarrow and try to push the wheelbarrow forward.
2. Repeat #1 with a medium sized wheel and then the largest wheel. Which was the easiest to push?
3. Measure the radius of the three sizes of wheels and axles. Calculate the mechanical advantage for each wheel size using the following equation:

$$\text{Mechanical Advantage} = \frac{\text{radius of the wheel}}{\text{radius of the axle}}$$

Discussion (Length: 10 minutes)

Activity I:
How did placement of the load within the wheelbarrow affect the mechanical advantage? Which position within the wheelbarrow resulted in the highest mechanical advantage? Why? The further you are away from the load and the closer the load is to the axle, the easier it will be to lift. Does the wheelbarrow have a first, second or third class lever? Class 2. The fulcrum is at one end and the load is between the fulcrum and the handles.

Activity II:
How does the axle provide mechanical advantage? When the wheel is turned, the axle also turns. The axle multiplies the torque applied to the wheel. The larger the difference between the wheel radius and the axle radius, the greater the mechanical advantage.

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GROUND**RULES**

MINING PROCESSES

Mining Processes
AGES 15-18

DEVELOP A CLOSURE AND RECLAMATION PLAN

Description

Students will develop a closure and reclamation plan for a real or fictitious mine site. They will determine what the area will be used for after reclamation, what steps they will take to reclaim the land and what resources they will require. They will draw a diagram of the reclaimed landscape.

VOCABULARY:

1. Reclamation
2. Closure plan
3. Progressive reclamation

MATERIALS:

- *Ground Rules* film
- Access to the internet
- Paper and pencils or computer graphics program
- Mine site case study with diagram of mine site during operation (can be fictitious)

Introduction (Length: 30 minutes)

Watch Chapter 8 “Reclamation” of the *Ground Rules* film.

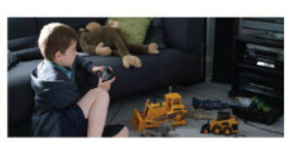
Ask the students what is meant by reclamation. Reclamation refers to the process of restoring the land that was disturbed by a mining operation to create an environment that is safe and productive for use by future generations. Discuss the possible safety and environmental issues that could result if the mine site was not reclaimed.

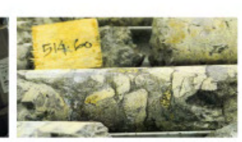
For modern mines, reclamation has to be planned out in advance of opening the mine. This is called “Closure or Reclamation Planning”. Mining companies have to prepare a plan and have it approved by the government.

Ask the students what they noticed about the natural vegetation in the New Guinea site compared to the natural vegetation in the Wyoming site? Ask them which site they think would be easier to reclaim. Discuss the fact that the goal of reclamation is to create a landscape that is as close to the natural landscape as possible, but that this will be much harder to achieve in a rain forest than in a prairie region.

Review examples of mine sites in your country, state or province that have been reclaimed. What type of landscape was created after reclamation? What types of structures were reclaimed and how were they reclaimed? (the Mineral Information Institute has several profiles of reclaimed mine sites; www. mii.org)





Activity (Length: 60 minutes)

The objective of this activity is to develop a plan for closure and reclamation of a mine site. Students can work alone or in groups.

Preparation:
1. Prepare a case study for this activity based on a fictitious mine site or a real mine site that is active or has been rehabilitated in your country, state or province.
2. Obtain or create a simple diagram of the mine site during operation.
3. If the mine site is fictitious, create a description of the mine (what type of mine, what product was mined, where it is located, details about the nearest community, etc.). If it is an actual mine site, the students can research this information on their own.

Activity:
1. Using the information provided by your teacher, design a closure and reclamation plan for the mine site.
2. Describe how the area will be used following closure and reclamation.
3. Describe how each of the features of the mine will be closed and reclaimed (open pit mine, underground mine, tailings ponds, waste rock stockpiles, buildings, access roads, airstrips, etc.).
4. What resources will you need to construct the reclaimed landscape? (e.g., trees, grass, soil). Do any natural resources have to be saved before the mine is constructed (e.g., topsoil)?
5. Draw a diagram showing the mine site after reclamation.

Discussion (Length: 30 minutes)

Have each student/student group present their reclamation plan to the class.

If this activity is completed for an actual mining operation that has been rehabilitated, compare the students' plans with the actual reclaimed landscape.

If the mine is currently in operation, perhaps a mining company representative could come to the class to explain what the company is planning for future reclamation of the site.

Discuss the term "progressive reclamation". Explain that in some cases, reclamation of some structures can occur while the mine is still in operation. For example, in strip mining of coal deposits, once the coal has been removed from a section and mining operations have moved onto another section, the previously mined section can be reclaimed. In hard rock mines, stockpiles of waste rock can be reclaimed by laying soil on top and planting vegetation.

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GROUNDRULES

MINING PROCESSES | AGE: 15 TO 18 | LENGTH: 1.75HR | CURRICULUM: earth science, math, problem-solving

THE MINING PROCESS GAME

Description

Students will explore the various phases involved in the development of a mine and the economic aspects of these phases. They will gain an understanding of the decision-making processes involved in determining whether an ore body can be profitably mined.

VOCABULARY:

1. Exploration
2. Claim
3. Drilling
4. Ore body
5. Waste rock
6. Mineral valuation
7. Gross and net profit

MATERIALS:

- *Ground Rules* film
- Approximately 500 poker chips (same color)
- Five colors of paint (yellow, blue, green, red and black) and brushes
- Graph paper
- Colored markers (same colors as paint)
- Timers
- Calculators
- Worksheet (included in lesson plan)

Introduction (Length: 30 minutes)

Watch Chapter 1 “Exploration” and Chapter 2 “Modern Mining” of *Ground Rules*.

Discuss the stages involved in the development of a metal mine. Emphasize the decision-making processes involved in deciding whether to develop a mine.

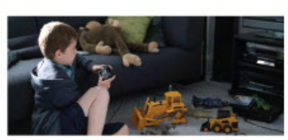
The first stage in the development of a mine is called “Mineral Exploration”. This phase involves identification of an ore body, mapping the location and extent of the ore body, staking a claim, drilling to collect core samples, analyzing the core samples for mineral content and chemistry, and determining the resource potential of the property.

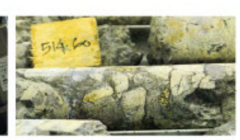
Introduce the concept of costs and benefits. In mining, there are a variety of costs, such as exploration work, regulatory processes, equipment, engineering challenges, mining labour, training, health and safety, and reclamation.

The benefits of mining arise from the value of the metals extracted. The grade or concentration of the metal as well as its form of occurrence will affect the costs associated with mining the ore. Therefore, the costs involved in extracting the ore must be weighed carefully against the value of the metal deposit to determine if the mine can be profitable. Mining companies usually conduct feasibility studies to determine the viability of potential mines.

Discuss the concept of mineral valuation. Different minerals have different values (for example, a pound of gold is worth much more than a pound of lead). The value of the mineral is determined by the demand for that mineral to make the things that we use in our everyday lives.





Discuss the process of extracting ore. Only a portion of the ore body contains the metals of interest. During the mining process, the metals of interest are extracted from the surrounding rock. The remaining waste rock must be disposed of in an environmentally responsible manner. Typically, the volumes of waste rock are far greater than the volumes of the metal. The company has to decide where to stock pile the waste rock and how to incorporate this into the reclaimed landscape at the conclusion of the mining process.

Activity I (Length: 60 minutes + 30 minutes preparation time)

The objective of the activity is to develop a profitable mining operation. Students should work in groups for this activity because in the real world, these decisions are made by teams of people.

Student Preparation (15 minutes):

1. Divide the class into three or four groups, representing mining companies.
2. Let each group name their company and create a company sign (that will be used for staking their mining claim).
3. Using the graph paper, each group should prepare a “base map” of the room where the activity will take place. The map should show all major features like doors, windows, desks, tables, cabinets, etc. To increase mapping precision, the map may be drawn to scale and compass direction, although this is not essential to the activity.

Teacher Preparation (30 minutes):

1. Assign each of the five paint colors to a mineral type. For example: yellow = gold, blue = silver, green = copper, red = iron, black = lead.
2. Paint a spot of one color on one side of approximately 25 to 30 poker chips. Do the same for the other four colors. The remaining unpainted poker chips will represent waste rock.
3. While students are out of the room, put the poker chips in clusters on desks, tabletops or countertops in various locations around the room (1 or 2 more clusters than there are groups of students). Each cluster represents a property which may or may not contain a valuable ore body. You can group different colors together to represent the ore bodies because several different minerals are often found together in nature (but each property should have a dominant mineral type and less of the other minerals).
4. Randomly place approximately 25% of the painted poker chips with the painted side up and the rest with the painted side down.
5. Add approximately three times as many unpainted poker chips to each cluster (i.e., waste rock).
6. Keep an answer sheet that indicates how many of each color of poker chips are used in each cluster.
7. Provide the following information to each company:
    a. A set of colored markers (matching the paint colors).
    b. A list of the poker chip colors and their corresponding mineral type. Students should add a legend to their map indicating which colors represent which mineral types (using the colored markers).
    c. The value of 1 poker chip of each type (use amounts in mine valuation section of the worksheet or similar values reflective of the relative value of these mineral types in the real world).

Activity:

Prior to starting the activity, explain that the poker chips represent minerals and waste rock and that some of the painted poker chips are upside down, so the full extent of the deposit is unknown. The objective of the activity is to develop the most profitable mine. Remind the students that time costs money in the mining process, so all phases of mining must be done as quickly as possible, but with careful thinking as well!

Phase 1: Site Reconnaissance

1. Set the timer for 10 minutes.
2. Using colored markers, two representatives from each company will visit each potential "property" and record dots on their base map where the known (i.e., chips with painted side face up) and unknown (i.e., face down) poker chips are located. THE POKER CHIPS CANNOT BE MOVED OR TURNED OVER AT THIS TIME. This is called an exploration map. THE POKER CHIPS CANNOT BE MOVED OR TURNED OVER AT THIS TIME.
3. When mapping is completed, stop the timer.
4. Each company must record on their worksheet the number of minutes used in the exploration phase and calculate the cost of exploration on their worksheet.

Phase 2: Staking the Claim:

1. Set the timer for 10 minutes.
2. During this time, each company should look over their exploration map and decide where they are going to "stake their claim" (i.e., which property they are going to mine).
3. When the timer goes off, one representative from each company will place their company sign on the property they want to claim.
4. If two or more companies claim the same property, a competitive bid will take place. Use a coin toss (or similar method) to decide who makes the opening bid ($20,000). Each company involved in the competitive bid will take turns deciding whether to find another property or to present their own higher bid price in increments of $20,000. The winner of the competitive bid process will control that property and record the bid price they paid for the property on their worksheet. The loser(s) must stake a claim on another property.

Phase 3: Exploration Drilling:

1. Set the timer for 10 minutes.
2. Each company must drill up to six holes on their property. Drilling consists of turning over up to 6 unknown poker chips to expose the mineral types on the underside of the poker chips. The group decides how many and which poker chips they will turn over.
3. Drilling must be completed before the timer goes off.
4. Calculate the cost of drilling on the worksheet.

Phase 4: Mine Development:

1. Each company will mine their whole property by turning over each remaining unknown poker chip.
2. Record the number of poker chips mined (i.e., the total number of poker chips). This includes unpainted poker chips (i.e., waste rock) and previously face-up poker chips because it also costs money to extract these from the ground.
3. Calculate the cost of mine development on the worksheet.

Phase 5: Mine Valuation:

1. Record the number of poker chips of each mineral type on the worksheet. Calculate the value of each mineral type and the total mineral revenue.

Phase 6: Waste Rock Disposal and Reclamation

1. Count the number of waste rock chips and record on the worksheet.

2. Decide where you are going to dispose of your waste rock. The waste rock chips have to be disposed in an area that is as close to your mine as possible, but the waste rock chips must have enough room to be stacked in a cone/pyramid shape with no spillage off desks, etc. (Furniture cannot be moved and waste rock cannot be piled on the floor)
3. Stack your waste rock chips in a cone/pyramid shape.
4. Measure the straight line distance from the centre of your mine site to the centre of the waste rock pile.
5. Calculate the cost of waste rock disposal on the worksheet.

Phase 7: Calculate Mine Profit:
1. Fill in the cost-benefit table on the worksheet.
2. Calculate the total costs, total benefits and gross profit.
3. Calculate reclamation costs and net profit.

Discussion (Length: 15 minutes)

Which company had the most profitable mine? Discuss the reasons why this mine was more profitable. For example, the ore body was richer in minerals that have high monetary value, exploration costs were minimized, competitive bids were avoided, etc. Discuss the decision-making processes involved in each stage of mine development. What was the most difficult decision to make?

Discuss the waste rock disposal and reclamation costs. What factors need to be considered for these activities? For example, how to stock pile the waste rock, where to put it while the mine is in the development phase and how to incorporate these into the reclaimed landscape.

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Worksheet

Company Name ______________________________ Date ________________

Phase 1: Site Reconnnaissance

Field/Mapping costs: $15,000 per minute (maximum 10 minutes)

__________ minutes x $15,000/minute = $ __________________

Phase 2: Staking The Claim

Fill in one of the following:

a) If you were the only company to stake the claim for your property, enter 0:
$ _________

b) If you paid a competitive bid to secure your property, enter bid price paid:
$ _________

Phase 3: Exploration Drilling

Drilling costs: $30,000 per poker chip (maximum of 6 per site)

__________ poker chips x $30,000/chip = $ ________________

Phase 4: Mine Development

Mining costs: $5,000 per poker chip

__________ poker chips x $5,000/chip = $ _________________

Phase 5: Mine Valuation

Gold:	_________	poker chips x $400,000	=	$ ______________
Silver:	_________	poker chips x $50,000	=	$ ______________
Copper:	_________	poker chips x $20,000	=	$ ______________
Lead:	_________	poker chips x $10,000	=	$ ______________
Iron:	_________	poker chips x $5,000	=	$ ______________
		Total Mineral Revenue (Sum)	=	$ ______________

Phase 6: Waste Rock Disposal

Waste rock disposal costs: $100 per waste rock chip x distance transported

Total cost for disposal of waste rock =

$100 x _______ waste rock chips x _________ cm = $ _____________.

Phase 7: Calculate Mine Profit

MINING PHASE	AMOUNT
Benefits	
Total Mineral Revenue	$
TOTAL PROJECT BENEFITS	**$**
Costs	
Site Reconnaissance	$
Competitive bid paid	$
Drilling	$
Mining	$
Waste rock disposal	$
TOTAL PROJECT COSTS	**$**
GROSS PROFIT (project benefits – project costs)	**$**
Reclamation costs (10% of gross profits)	$
NET PROFIT (gross profit – reclamation costs)	**$**

OREBODY MYSTERY

Description

Students will explore the processes of core drilling and geological testing. Students will collect core samples, analyze them for mineral content, map the extent of the ore body and determine its approximate area and volume.

VOCABULARY:

1. Exploration
2. Core sample
3. Mineral
4. Ore body
5. Waste rock
6. Grid sampling

MATERIALS:

- *Ground Rules* film
- Two colors of playdough
- 2 inch pieces of clear drinking straws
- A blunt stick (lollipop stick) that will fit inside the straw and is longer than 2 inches
- Graph paper and pencils
- Calculators
- Rulers
- Real rock core samples (optional)
- Magnifying glasses (optional)
- Blunt knife (optional)

Introduction (Length: 30 minutes)

Watch Chapter 1 “Exploration” of *Ground Rules* film.

Discuss the stages involved in the development of a metal mine. How do geologists determine where mining should occur?

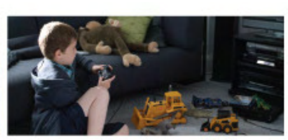
Ask the students if they know what an ore body is? Explain that an ore body is a large deposit of minerals. Geologists are looking for these deposits during the “exploration” stage of mining development.

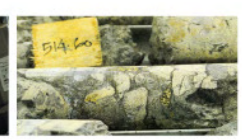
The exploration phase involves identifying an ore body, mapping the location and extent of the ore body, staking a claim, drilling to collect core samples, analyzing the core samples for mineral content and chemistry, and determining whether the property is suitable for mining.

Introduce the concept of costs and benefits. In mining, there are a variety of costs, such as exploration work, regulatory processes, equipment, engineering challenges, mining labor, training, health and safety, and reclamation.

The benefits of mining arise from the value of the metals extracted. The grade or concentration of the metal as well as its form of occurrence will affect the costs associated with mining the ore. Therefore, it is important to gain an accurate understanding of the geological properties of an ore body.





Explain that drilling to collect core samples is an important step in the exploration phase of mining. During geological exploration at a potential mine site, a drilling rig would be used to drill into the rock and extract cores of rock. These core samples would be analyzed for mineral content, chemistry and various other geological variables. All of this information would assist the mining company in determining if the ore body is rich enough to support a profitable mine.

Optional: If you are able to obtain a real rock core sample, pass it around for the students to examine. You can also use magnifying glasses to have a closer look at details within the sample. Ask them to describe what they see. Is the core sample one solid color or are there bands of multiple colors? Can they see different types of minerals within the sample?

Activity (Length: 45 minutes)

The objective of the activity is to accurately map the extent of an ore body and determine its volume based on core sampling results.

1. Divide the class into groups of 3 to 4 students.
2. For each group, tape a piece of graph paper to the desk and have the students draw a rectangle that almost completely covers the graph paper, but leaves one or two rows of grid squares visible along the edge. The lines of the rectangle should be drawn along the graph paper grid lines. Label the horizontal edge of the rectangle with letters – one in each grid square (i.e., A,B,C,D…). Label the vertical edge of the rectangle with numbers (i.e., 1,2,3 …). Prepare two more sheets of graph paper with the exact same rectangle dimensions and labeling (one will be the answer sheet and one will be the recording sheet).
3. Give each group two colors of playdough and explain what each color of playdough represents (e.g., red represents the ore body and green represents the surrounding base rock).
4. Have each group build an ore body on top of the graph paper within the boundaries of the rectangle. Students will place the ore body playdough color in several places within the rectangle boundary, not extending to the edges. They should vary the thickness of the playdough in each pocket.
5. Have each group map the ore body onto the answer sheet of graph paper and give it to the teacher.
6. Next, they will spread the base rock color on top of the whole structure, extending to the edges of the rectangle. They should end up with a structure where they only see the base rock color of playdough from the top and sides.
7. Groups should switch positions so they are working on another group's ore body.
8. Within each group, students will take turns taking core samples from the ore body. Core samples are collected by pushing the straw straight down into the playdough structure, pulling it up, poking the core sample out with a stick and examining it. Use the grid squares and associated numbers and letters on the axes of the graph paper to accurately locate the position of your core samples.
9. Students will record core sample results on the recording sheet of graph paper. If no mineral colors are visible, enter O in the grid square.
10. If the ore body color is visible, students should measure the depth of the ore body using a ruler. Pick a consistent unit of measurement (e.g., millimeters) and record the depth measurement in the grid square.
11. Continue sampling until your group thinks they have enough information to map out the pockets of the ore body and determine each pocket's approximate volume.
12. Record the number of core samples taken.

13. Map the ore body on the recording sheet of graph paper and compare to the answer sheet for that ore body.
14. Count up the number of full and partial grid squares occupied by each pocket of the ore body to calculate the area of each pocket and the total area of the deposit. Count each partial grid square as one-half of a square.
15. Determine the approximate volume of each pocket using an average of the recorded depth measurements.

Optional Cross-Section Diagram:
Draw a straight line through the playdough structure. Have students collect core samples along the line and measure the distance from the top of each core sample to the ore body, and the depth of the ore body. Students can use this information to draw a cross-section of the ore body. Slice through the playdough structure along the line and compare the cross-section diagrams to the actual cross-section.

Discussion (Length: 15 minutes)

How accurate was each group in determining the shape of their ore body? Which group had the most accurate ore body map? Which group used the least number of core samples to generate their map? Based on the area and volume calculations, which property would be the most profitable to mine? Where should mining begin within that property?

Discuss how this exercise relates to core sampling in a real ore body. Why is it important to accurately determine the shape of the ore body? Why is it important to limit the number of core samples used to determine the shape of the ore body?

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Playdough Recipe

Combine 1 cup flour, ¼ cup salt, and 2 tablespoons cream of tartar with 1 cup water, 2 teaspoons food coloring and 1 tablespoon oil in a saucepan. Cook and stir 3-5 minutes, or until it sticks together in a ball. Knead for a few minutes on a lightly floured surface. Store in an air-tight container.

RECLAIMING A MINE SITE

Description

Students will learn how overburden is stockpiled and incorporated into the landscape after closure of a mine. They will experiment with growing plants on reclaimed landscapes with various treatments. Students will test five variables: soil thickness, soil composition (layering or mixing), slope, nutrients and seed type.

VOCABULARY:

1. Overburden
2. Stockpile
3. Grading
4. Soil types
5. Seeding
6. Slope
7. Seed germination
8. Nutrients
9. Closure planning
10. Erosion

MATERIALS:

- *Ground Rules* film
- Mixture of gravel, sand and silt (overburden)
- Potting soil
- Bone meal, blood meal and potash, or mixed fertilizer, teaspoons
- Grass seeds, bean seeds
- Water and spray bottle
- Access to sunlight or a lamp
- Shoebox sized plastic tubs, small trowels
- Measuring cups, large mixing bowls
- Large plastic storage tubs or crates
- Rulers, calculators
- Toothpicks, landscape fabric
- Data sheet (provided)

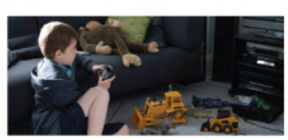
Introduction (Length: 15 minutes)

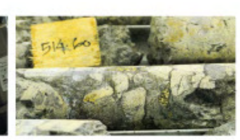
Watch Chapter 8 “Reclamation” of the *Ground Rules* film. Ask the students why mine sites have to be reclaimed after the mine has closed. Discuss the possible safety and environmental issues that could result if the mine site was not reclaimed.

Ask the students what was removed at the coal mine before they could get to the coal deposit. The top layer of soil (60 meters thick) had to be removed. This is called “overburden”. Ask the students what the mining company did with the overburden. They stockpiled it on the mine site and saved it for reclamation. Emphasize the fact that reclamation has to be planned out in advance of opening the mine. This is called “Closure Planning”. Mining companies have to prepare a closure plan and have it approved by the government. They also have to show that they will make enough profit during the operation of the mine to cover the costs of reclamation.

Ask the students what they noticed about the natural vegetation in the New Guinea site compared to the natural vegetation in the Wyoming site? Ask them which site they think would be easier to reclaim. Discuss the fact that the goal of reclamation is to create a landscape that is as close to the natural landscape as possible, but that this will be much harder to achieve in a rain forest than in a prairie region.





Explain that the students will be building model reclaimed landscapes and attempting to grow plants on top of them. Show the class what the overburden looks like (mixture of gravel, sand and silt). Ask them if they think plants will grow directly on top of this. Ask the students what plants need to grow – soil with nutrients, water, sunlight. Ask them how they think they can get plants to grow on top of overburden. Explain that they will be experimenting with different types of soil and nutrient mixtures to see which is the best for plant growth.

Activity I (Length: 30 minutes + 5 minute daily observations)

The objective of this activity is to investigate how plants will grow on top of a reclaimed landscape with various treatments. Students will test four variables: soil thickness, soil composition (layering or mixing), slope, and nutrients.

<u>Building a Reclaimed Landscape</u>

1. Divide the class into eight groups. Give each group a small plastic tub and a garden trowel. The teacher should also have a tub and trowel.
2. Each group should label their plastic tub with their group number (1 to 8) and the teacher should label his/her tub as 9.
3. Each group should calculate the area of the bottom of their tub by multiplying the length times the width.
4. Each group will have to determine the volume of overburden required to make a 5 cm (2 inch) layer in the bottom of their tub by multiplying the area of their tub by 5 cm (2 inches). Each group should measure out the appropriate volume of overburden.
5. Each group will prepare a different reclaimed landscape model with different thicknesses and mixtures of soil. Use the method in Step 4 to calculate soil volumes required to prepare various thicknesses of soil layers.
6. Each group should describe the composition of all of the reclaimed landscapes on their data sheet.

Group 1 (flat landscape, thin soil layer):

1. Pour the measured overburden into the bottom of the plastic tub and smooth it out to make an even surface of uniform thickness. Measure the depth of the layer with a ruler in several places throughout the tub to ensure that it is uniform thickness.
2. Measure out a volume of potting soil that will make a layer exactly 1 cm (1/2 inch) thick when placed on top of the overburden layer.
3. Spread the potting soil directly on top of the overburden layer being careful not to mix the two layers.

Group 2 (flat landscape, thin soil layer, fertilizer):

1. Pour the measured overburden into the bottom of the plastic tub and smooth it out to make an even surface of uniform thickness. Measure the depth of the layer with a ruler in several places throughout the tub to ensure that it is uniform thickness.
2. Measure out a volume of potting soil that will make a layer exactly 1 cm (1/2 inch) thick when placed on top of the overburden layer. Put in a mixing bowl.
3. Add 1 teaspoon each of bone meal, blood meal and potash (or 1 teaspoon of a mixed fertilizer). Mix the fertilizer thoroughly into the potting soil.
4. Spread the mixture in a layer on top of the overburden mixture being careful not to mix the two layers.

Group 3 (flat landscape, thick soil layer):

1. Pour the measured overburden into the bottom of the plastic tub and smooth it out to make an even surface of uniform thickness. Measure the depth of the layer with a ruler in several places throughout the tub to ensure that it is uniform thickness.
2. Measure out a volume of potting soil that will make a layer exactly 4 cm (1 ½ inches) thick when placed on top of the overburden layer.
3. Spread the potting soil directly on top of the overburden layer being careful not to mix the two layers.

Group 4 (flat landscape, thick soil layer, fertilizer):

1. Pour the measured overburden into the bottom of the plastic tub and smooth it out to make an even surface of uniform thickness. Measure the depth of the layer with a ruler in several places throughout the tub to ensure that it is uniform thickness.
2. Measure out a volume of potting soil that will make a layer exactly 4 cm (1 ½ inches) thick when placed on top of the overburden layer. Put in a mixing bowl.
3. Add 3 teaspoons each of bone meal, blood meal and potash (or 3 teaspoons of a mixed fertilizer). Mix the fertilizer thoroughly into the potting soil.
4. Spread the mixture in a layer on top of the overburden mixture being careful not to mix the two layers.

Group 5 (flat landscape, mixed overburden and soil):

1. Put the measured overburden in a mixing bowl.
2. Measure out a volume of potting soil that will make a layer exactly 2.5 cm (1 inch) thick when placed on top of the overburden layer. Add to the mixing bowl.
3. Mix the potting soil and overburden thoroughly. Pour into the plastic tub. Smooth the surface. Measure the depth of the layer with a ruler in several places throughout the tub to ensure that it is uniform thickness.

Group 6 (flat landscape, mixed overburden and soil, fertilizer):

1. Put the measured overburden in a mixing bowl.
2. Measure out a volume of potting soil that will make a layer exactly 2.5 cm (1 inch) thick when placed on top of the overburden layer. Put in a mixing bowl.
3. Add 2 teaspoons each of bone meal, blood meal and potash (or 2 teaspoons of a mixed fertilizer).
4. Mix the potting soil-fertilizer-overburden mixture thoroughly. Pour into the plastic tub. Smooth the surface. Measure the depth of the layer with a ruler in several places throughout the tub to ensure that it is uniform thickness.

Group 7 (sloped landscape):

1. Pour the measured overburden into the bottom of the plastic tub and smooth it out into a smooth, inclined slope with an angle of 45º.
2. Measure out a volume of potting soil that will make a layer exactly 1 cm (1/2 inch) thick (if it was lying horizontal in the tub).
3. Spread the potting soil evenly over the surface of the overburden layer being careful not to mix the two layers and to maintain the 45º slope.
4. If potting soil tends to slide downhill, add toothpicks and strips of landscape fabric in two rows perpendicular to the slope.

Group 8 (sloped landscape, fertilizer):

1. Pour the measured overburden into the bottom of the plastic tub and smooth it out into a smooth, inclined slope with an angle of 45º.
2. Measure out a volume of potting soil that will make a layer exactly 1 cm (1/2 inch) thick (if it was lying horizontal in the tub). Put into a mixing bowl.

3. Add 1 teaspoon each of bone meal, blood meal and potash (or 1 teaspoon of a mixed fertilizer). Mix the fertilizer thoroughly into the potting soil.
4. Spread the potting soil-fertilizer evenly over the surface of the overburden layer being careful not to mix the two layers and to maintain the 45º slope.
5. If potting soil tends to slide downhill, add toothpicks and strips of landscape fabric in two rows perpendicular to the slope.

Adding the Plants (all groups)

1. Each group and the teacher should sprinkle 4 teaspoons of grass seed as evenly as possible across the surface of their reclaimed landscape.
2. Gently pat the seeds into the surface of the soil.
3. Using the spray bottle of water, the teacher should spray a generous amount of water evenly over the surface of his/her reclaimed landscape. The total number of sprays used should be counted and recorded.
4. Each group should then spray their reclaimed landscapes with the same number of sprays.
5. Place all of the tubs near a window or under a lamp that is turned on during the day and off at night.

Daily Observations (all groups)

1. Water the model reclaimed landscapes every day using a spray bottle, making sure to apply the same number of sprays to each tub. Give them extra water on Fridays so they will have enough to get through the weekends.
2. Each group should make daily observations of all of the reclaimed landscape models on their data sheet. Continue making daily observations until the grass is growing well on at least one of the models.

Activity II (Length: 30 minutes + 5 minute daily observations)

The objective of this activity is to build a larger reclaimed landscape model with variable topography incorporating two different kinds of seeds. This activity can be conducted simultaneously with Activity I or it can be conducted after Activity I, incorporating the knowledge gained from the first activity. The activity can be conducted in groups or as one large class project.

In a large plastic storage tub or crate, design a reclaimed landscape with variable topography. Include hills and valleys, slopes of different angles, and flat areas. Use whatever combinations of potting soil, fertilizer and other soil types as you would like. The only condition is that the entire volume of overburden removed from your mine site must be used – no more and no less (the teacher should determine an appropriate amount based on the size of the container being used). Apply grass seed to the entire landscape. Plant some bean seeds in some locations. Use landscape fabric and toothpicks where needed to keep topsoil in place on slopes. Carefully measure and record the details of the treatments used. Record volumes, areas, slopes and other pertinent information about the reclaimed landscape. Place model in an area that receives sunlight or under a lamp. Water the landscape daily and record daily observations.

Discussion (Length: 30 minutes)

Activity I:
What variables were kept constant in this experiment? Water, light, grass seed, overburden layer volume. What variables were tested in this experiment? Potting soil thickness, layered vs. mixing of potting soil and overburden, slope, and nutrients. What other variables could have been tested? Different types of seeds, different amounts of fertilizers, different slope angles, etc.

On which reclaimed landscape(s) did the plants grow the best/worst? On which reclaimed landscape(s) did plants grow the fastest? On which reclaimed landscape(s) did plants look the healthiest? Were the students hypotheses correct? What do plants need to grow on a reclaimed landscape? Based on the results of the experiment, if you were planning a reclaimed landscape, how would you design it?

Did the potting soil layer in the sloped landscapes stay in place throughout the experiment? Discuss erosion and the challenges this presents when reclaiming sloped landscapes.

Explain that this experiment is a simple demonstration of reclamation of a flat or sloped landscape to a grassland ecosystem. Discuss what would be required to reclaim a landscape to a forest ecosystem.

Activity II:
Discuss the observations made in this experiment. On which area(s) of the reclaimed landscape did the grass grow the best? How did plants grow on slopes compared to flat areas? Which slopes worked the best?

How did the bean seeds grow compared to the grass seeds? Which type of seed germinated faster? Why might germination time be important for a reclaimed landscape? Discuss wind erosion and removal of top soil. The bean plants in this experiment may represent trees on a reclaimed landscape. It is important to get vegetative cover established on reclaimed landscapes as quickly as possible to retain the soil (grasses) and then it will be possible to add other types of slower growing plants, such as trees.

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Reclaim a Mine Site Data Sheet

A) Initial Observations and Hypotheses Date: ___________

1. Describe the composition of the reclaimed landscapes

   Landscape 1:

   Landscape 2:

   Landscape 3:

   Landscape 4:

   Landscape 5:

   Landscape 6:

   Landscape 7:

   Landscape 8:

   Landscape 9:

   Which landscape is the control? Why?

2. On which landscape do you think plants will be able to grow the best? Why?

3. On which landscape(s) do you think plants will not grow at all. Why?

4. What do think will be the challenges involved in growing plants on a sloped surface compared to a flat surface?

B) Daily Observations

Number of days until plants start to grow in at least one of the reclaimed landscapes: __________

On the first day plant growth is visible in at least one of the reclaimed landscapes, start making daily observations by filling in a table for each day. Copy the following table for each day as required until the end of the experiment.

Date: _________________

Observations	1	2	3	4	5	6	7	8	9
Growth visible? (Y/N)									
% of surface covered with plants (%)									
Height of tallest plant (mm)									
Do plants look healthy? (Y/N) Describe.									
Other observations									

GROUNDRULES

MINING PROCESSES | AGE: 15 TO 18 | LENGTH: 1.5HR | CURRICULUM: earth science, social/environmental

WHAT ARE THE GROUND RULES?

Description

Students will participate in the planning process for a fictitious mine site in a remote area. They will consider the engineering challenges, environmental impacts and social implications involved in developing the mine.

VOCABULARY:

1. Engineering challenges
2. Impacts & Benefits
3. Communication
4. Social context
5. Environmental context

MATERIALS:

- *Ground Rules* film
- Fictitious or real mine site description
- Paper and pens

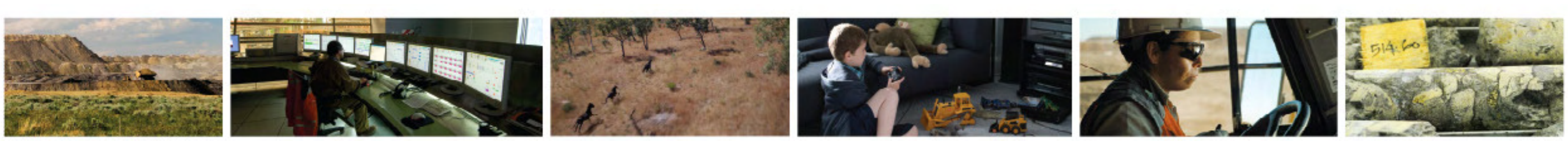
Introduction (Length: 30 minutes)

Watch Chapters 4 “Engineering Challenges”, 6 “Mining and the Community” and 7 “Mining and the Environment” of the *Ground Rules* film.

Discuss the challenges associated with developing the Grasberg Mine in Papua Indonesia (Chapter 4). Ask the students to recall some of the challenges: road to the top of the mountain, creating a whole new town site, finding people to work at the mine and providing them with the necessary skills and safety training, building the mill and plant site at such a high elevation and in a narrow valley, building a tramway to get workers to the ore body, getting the big mining trucks and equipment up to the mine site. Discuss the pros and cons of hiring already trained, skilled workers from abroad versus training local people to do the work. Why would a mining company want to spend so much money building a town site and educating local people to work at its mine?

Discuss the social context of mining using the example of the Newmont gold mine in Ghana (Chapter 6). What are some of the reasons why a community might not want a mine site to be located nearby? What are some of the possible benefits mining can provide to impoverished communities? (education, health care, employment) How can mining change the way of life of a community? What is the social groundwork that must be undertaken prior to even thinking about developing a mine site? (developing a working relationship with local people) Discuss the importance of open communication between the mining company and the local people. What are some of the challenges associated with communication? (language, cultural differences) Discuss the impacts and benefits of the mine on the economy of the local community.

Discuss the environmental context of mining using the example of the McArthur River Mine in Australia (Chapter 7). What does an environmental manager do at a mine site? What are some of the possible environmental impacts of a mine? (water quality, air quality, land disturbance, removal of vegetation/habitat). What major environmental challenge did Xstrata have to overcome before it could open the mine? (rerouting of the river). Discuss



the challenges associated with rerouting the river (maintaining biodiversity, maintaining natural features of a river channel, water quality).

Activity (Length: 60 minutes)

The objective of this activity is to gain an understanding of the types of engineering, social and environmental challenges associated with developing a mine site in a remote location.

Preparation:
Use information from an actual mine site or create a fictitious mine site in a remote area. Prepare a situation for the class to investigate. Write a short description of the proposed mine site. Name the location of this mine site and briefly describe the physical, social and environmental context.

Activity:
1. Divide the class into three teams: engineering team, environmental team and social team.
2. Give the students a few minutes to read over the situation description.
3. The engineering team must develop a plan to overcome all of the physical challenges associated with developing a mine site in that location.
4. The environmental team must develop a list of the potential environmental impacts of the proposed mine and develop a plan to mitigate against or monitor those impacts.
5. The social team must determine the potential social impacts and benefits of the mine site on the local community. Then they must develop a communication plan.
6. Have the groups present their plans to the class.

Discussion (Length: 30 minutes)

After each team presents their plan, the other two teams can ask questions and determine if the presenting team's plan would work. Did they miss any important considerations? Although each of the teams developed the plans in isolation, this wouldn't be true in the real world. The three teams would have to talk to each other to make sure that their plans would work together smoothly. Would the three plans developed in this activity work together? What aspects might be in conflict? What aspects might be complementary? What might be the most difficult challenge to overcome in this example?

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GROUNDRULES

ORE PROCESSING

Ore Processing

AGES 11-13

ELECTROPLATING PENNIES

Description

Students will conduct an experiment to simulate the process of electrowinning that is used in the purification stage of ore processing. In this experiment, they will electroplate zinc onto a copper penny.

VOCABULARY:

1. electrowinning
2. electroplating
3. anode
4. cathode
5. cation
6. anion
7. purification
8. electrolyte

MATERIALS:

- *Ground Rules* film
- Lab coats, safety goggles and gloves
- Shiny copper penny
- Zinc anode (available at boating stores)
- Flashlight battery (1 ½ volts)
- Wires to connect battery
- 500 mL beaker
- Vinegar, epsom salt, table sugar
- Toothbrush and toothpaste

Introduction (Length: 15 minutes)

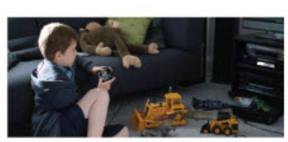
Watch Chapter 2, “Modern Mining” of the *Ground Rules* film. This chapter shows how copper is mined and processed at a large mine site in Chile.

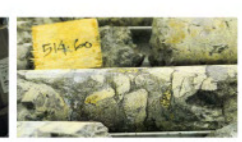
Review the steps involved in processing copper ore, as mentioned in the film: crushing, extraction, concentration, smelting and purification (electrowinning). First the ore is crushed into a fine powder to increase the surface area for further processing. Next, the copper is extracted and concentrated by froth flotation in which ground ore is mixed with reagents in an aerated tank filled with water. The hydrophobic copper sulfide particles attach to the air bubbles and float to the surface where they form a froth that is skimmed off (see Lesson Plan on Copper Extraction for more details on this process). Next, the copper concentrate is smelted at high temperatures to form a liquid called copper matte, which is further purified by the removal of sulfur as sulfur dioxide, resulting in an end product called “copper blister” which is approximately 98-99% copper. Finally, in the purification process, copper is refined using a process called electrowinning. Explain that in this activity, they will be exploring the process of electrowinning.

Electrowinning is based on the process of electroplating. Ask the students if they know what electroplating is. Review the terms anion, cation, anode and cathode. Explain that electroplating involves movement of positively charged ions (cations) from an anode through a salt solution. The cations in the salt solution are then attracted to the cathode, where they deposit onto it in metallic form.

In the process of copper purification shown on the film, copper from the unpurified anode is electroplated onto a sheet of pure copper at the cathode. The copper (at the cathode) is





the final product of copper processing. It is usually prepared in sheets that are 1 cm thick and approximately 1 meter square, weighing approximately 200 pounds.

Explain that electrowinning can be used to plate out various metals. In this activity, they will be trying to electroplate zinc onto a copper penny.

Activity (Length: 30 minutes)

The objective of this activity is to explore the process of electroplating using zinc and a copper penny. This activity can be done as a class demonstration or in student groups.

Preparation:
1. Fill the beaker approximately half full with vinegar.
2. Soak the zinc anode in the vinegar for several hours prior to the activity to dissolve some of the zinc.

Activity:
1. Put on a lab coat, safety goggles and gloves.
2. While wearing plastic gloves, carefully scrub the penny with toothpaste on a toothbrush. Rinse with water and pat dry. Use gloves to handle the penny at all times to avoid getting oils from your fingers on the penny.
3. Remove the zinc anode from the solution.
4. Add 100 grams per liter of Epsom salts and 120 grams per liter of table sugar to the beaker. Stir the solution thoroughly to mix.
5. Connect the positive end of the battery to the zinc anode and the negative end of the battery to the penny.
6. Immerse the penny and zinc anode in the solution. Don't let them touch each other. In a few minutes, the zinc should begin to plate onto the penny.
7. Let the electroplating continue for the rest of the class and look at it again at the end of class. If it is still difficult to see the zinc plating, give the penny another scrub with toothpaste to shine up the zinc coating.

Discussion (Length: 15 minutes)

Ask the students to explain what happened in the experiment. How does this experiment demonstrate the process of electrowinning used in the metal purification processes? Why is it necessary to remove the impurities from the zinc or copper using this process (i.e., why is 98-99% purity insufficient)?

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.

ORE PROCESSING | AGE: 11 TO 13 | LENGTH: 1.5HR | CURRICULUM: earth science, ore processing

EXTRACTING COPPER FROM SULFIDE ORES

Description

Students will extract copper from sulfide ores by simulating the crushing, milling and flotation processes.

VOCABULARY:

1. Crushing
2. Milling
3. Froth Flotation
4. Sulfide ores
5. Copper
6. Slurry
7. Tailings
8. Waste rock

MATERIALS:

- *Ground Rules* film
- Hammer
- Large container
- Old socks
- Safety glasses
- Sulfide ore
- Plastic container (shoebox size), water
- 4 plastic cups (8 oz), plastic jar with lid
- Steel shot (1/2 - 1 cm; 1/4 - 3/8 inch)
- Wire mesh screen (1/2 cm; 1/4 inch)
- Small bottle of bubble bath liquid
- 2 index cards, laminated
- Drinking straws, teaspoons, paper towels

Introduction (Length: 15 minutes)

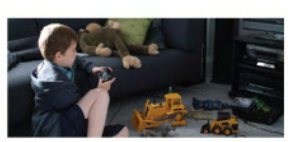
Watch Chapter 2 “Modern Mining” of the *Ground Rules* film. This chapter shows how copper is mined and processed at a large mine site in Chile.

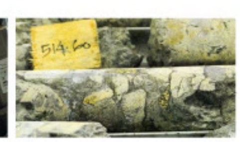
Pass around a piece of sulfide ore. Tell the class there is copper in the ore. Ask them how they think they could liberate the copper particles from the ore? Discuss the crushing process used in mining to extract valuable minerals from waste rock. The crushing process involves breaking up the ore into small pieces (up to 20 cm or 8 inches in diameter), so it can be handled effectively in the next phase of ore processing: milling.

Ask the class if they know what happens in the milling process. The milling process breaks the ore pieces into fine particles. In milling, the crushed ore and liquid are put into large rotating drums called mills. There are a variety of different types of mills. Typically, steel balls or rods are added to the mills. Why? The steel collides with the ore and assists in breaking it into smaller pieces. At the end of the milling process, a slurry of fine particles and water is produced. In the final step of the milling process, chemicals are added to the slurry to prepare the copper minerals for separation from the powdered rock.

Ask the class how they think the copper can be separated from the rest of the slurry. In the next phase of ore processing, copper minerals can be removed by flotation. A detergent-like substance called a frother and chemical reagents called collectors are added to the slurry. The collectors adhere only to the copper minerals, not the other particles of rock.





When air is forced through the slurry, the mixture attaches to the air bubbles and floats to the top of the liquid. The copper then ends up in the froth which floats on the surface of the tank and is skimmed off the top. The substance that is skimmed off the top is call "copper concentrate". The copper concentrate is cleaned, dewatered, filtered, dried and shipped to a smelter.

Explain that the students will be conducting an experiment to simulate the processes of crushing, milling and froth flotation.

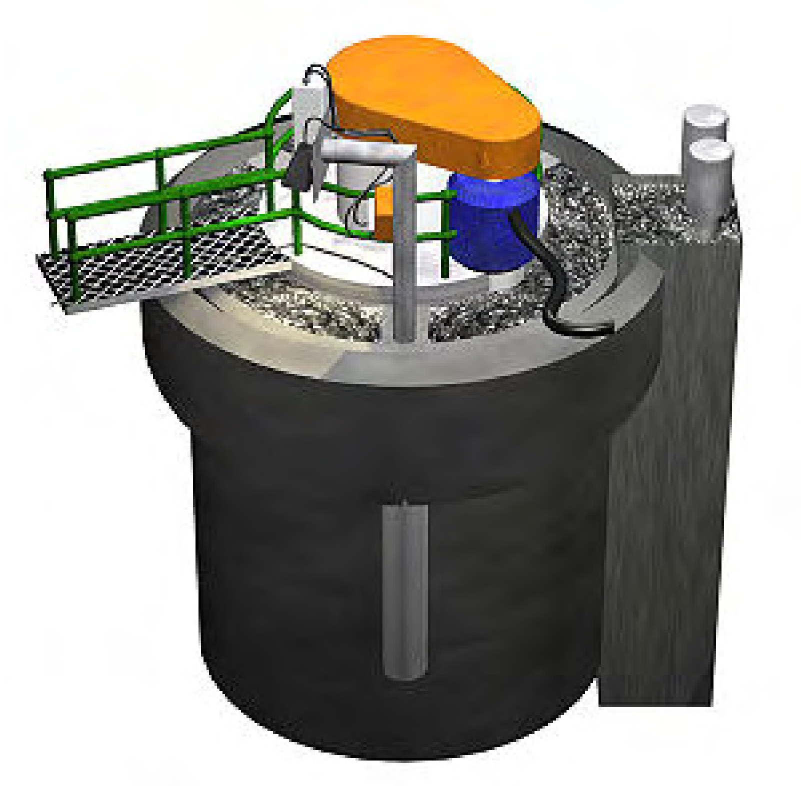


Figure 1 Froth Flotation Cell

Activity (Length: 60 minutes)

The objective of this activity is to extract copper from sulfide ore by simulating the crushing, milling and flotation processes.

Divide the class into groups of 3 students.

<u>Step 1: Crushing Process</u>

1. Put on safety glasses to protect eyes from flying bits of rock. Keep them on at all times during this activity.
2. Place a few pieces of sulfide ore inside an old sock.
3. Place the sock containing the sulfide ore pieces on a hard, flat surface.
4. Use a hammer to crush the sulfide ore into quarter-sized and smaller pieces.

5. Place all of the pieces of ore that are quarter-sized or smaller into the large container.
6. Answer the question on the data sheet under “Crushing Process”.

Step 2: Milling Process
1. Using a marker, label three 8 oz plastic cups as 1, 2 and 3.
2. Fill the jar approximately 1/3 full with crushed sulfide ore and steel shot. Keep a few pieces of the ore and steel shot aside.
3. Add water to the jar until the ore and shot are submerged by approximately 1 cm. Screw the lid tightly onto the jar.
4. Wrap the jar in the towel and shake for 2 minutes.
5. Place the wire mesh screen over the shoebox sized container. Pour the mixture from the jar onto the screen.
6. Pour the liquid from the shoebox-sized container into the 8 oz plastic cup labeled “1”. Check to make sure you have gotten all of the fine material out of the container. Observe the ore, the steel shot and the water. Compare the ore and steel shot to the pieces set aside and record observations on the data table in the space labeled “Trial 1”.
7. Return oversize pieces of ore to the jar and repeat steps 3 to 6 two more times. Pour the slurry from Trials 2 and 3 into the plastic cups labeled “2” and “3”, respectively.
8. After each trial, compare the reserved steel shot, the ore and the water in each cup. In the data table on the milling process section of the data sheet, record any noticeable changes in the size and shape of the ore and steel shot and any changes in the water.
9. Set aside all three cups of slurry for the Flotation Process.
10. Separate remaining large pieces of ore from the steel shot. Place both materials on a paper towel to dry.
11. When all materials are dry, return them to the original containers.
12. Clean the jar and shoebox container being careful not to wash any of the remaining slurry into a drain.
13. Answer the questions in the “Milling Process” section of the data sheet.

Step 3: Flotation Process
1. Each group should designate one student as the “recorder” who will record observations for the group and two students as the “experimenters” who will conduct the experiment.
2. Set aside slurry cup “1” from the Milling Process for observation.
3. Add 4 to 6 teaspoons of the bubble bath liquid into slurry cup “2” and stir the contents.
4. Place one straw each into slurry cups “2” and “3”. The two experimenters in each group should blow gently but steadily through each straw for 30 seconds.
5. Use the index cards to scrape any bubbles off the top of the slurry in each cup and place them on separate paper towels to dry. Label the deposited bubbles as “Trial 1”.
6. The recorder of each group should record the group’s observations for “Trial 1” on the data sheet while the experimenters should proceed immediately to Step 7. Don’t allow the cups to “rest” between trials.
7. The experimenters should begin “Trial 2” by repeating steps 4 to 6. Then repeat again for “Trial 3”. After each trial, the recorder should record the group’s observations on the data sheet.
8. Dispose of the slurries by placing them in a garbage receptacle lined with a strong plastic bag. Do not pour slurry into a drain.
9. Answer the questions in the “Flotation Process” section of the data sheet.

Discussion (Length: 15 minutes)

Review the observations made by each of the groups and the answers to the questions on the data sheet.

What happens to the remaining rock fragments left behind at the bottom of the flotation tank? This mixture, known as tailings, is typically pumped to a tailings impoundment where the water is removed and recycled back into the flotation process. The remaining waste rock must be stockpiled and eventually incorporated into the reclaimed landscape after mining operations have ceased.

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Extracting Copper from Sulfide Ore Data Sheet

Crushing Process:

Was it easy or difficult to crush the sulfide ore into small pieces?

Milling Process:

Trial	Changes in Sulfide Ore	Changes in Steel Shot	Changes in Water
1			
2			
3			

What does the jar represent?

What is the purpose of the steel shot?

What is the purpose of the screen?

Why is the milling process necessary?

Flotation Process:

Record the behavior of each slurry cup after each trial in the following table:

Trial	Slurry Cup 1 (slurry only; control)	Slurry Cup 2 (slurry with bubble liquid and air)	Slurry Cup 3 (slurry with air)
1			
2			
3			

What was observed collecting onto the bubbles?

Was all of the copper in the slurry collected after 4 trials?

ORE PROCESSING	AGE: 11 TO 13	LENGTH: 1 HR	CURRICULUM: earth science, ore process, mixtures

FLOATING COAL

Description

Students will explore the process of froth flotation to separate coal from a mixture of coal and sand.

VOCABULARY:

1. Froth flotation
2. Hydrophobic
3. Hydrophilic
4. Surface tension
5. Slurry
6. Concentrate
7. Tailings
8. Mixtures

MATERIALS:

- *Ground Rules* film
- Clear glass jar
- Liquid detergent and eye dropper
- Vegetable oil and eye dropper
- Stirring rod
- Silica sand (approx. same size as coal particles)
- Fine powdered coal, with some larger flakes
- Filter paper (can use coffee filters)
- Data sheet (provided)

Introduction (Length: 15 minutes)

Watch Chapter 8 “Reclamation” of the *Ground Rules* film. This chapter shows how coal is mined at a mine site in the United States.

Pass around a mixture of sand and coal. Ask the students how they think they could extract the coal from the sand. Suggest the idea of using a sieve to separate the particles. Ask the students if that would work. Explain that a sieve would not work because some of the sand particles are the same size as the coal particles.

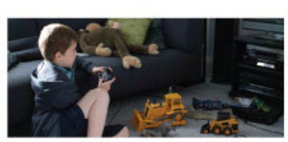
Explain that froth flotation is a process that can be used to remove coal from the sand. This process can also be used to separate valuable metals from ore (see Lesson plan on copper extraction for more details). Explain that the students will be conducting an experiment to separate coal from a coal-sand mixture using the process of froth flotation.

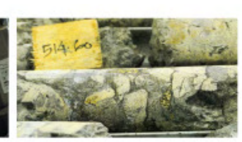
Activity (Length: 30 minutes)

The objective of this activity is to separate coal from a coal-sand mixture using the process of froth flotation.

1. Divide the class into groups of two.
2. Have each group fill the glass jar approximately 2/3 full with tap water, secure the lid and shake vigorously. Stop shaking and let stand for a few seconds. Answer the questions in Section A of the data sheet.





3. Add 2 drops of detergent to the tap water, secure the lid and shake vigorously. Stop shaking and let stand for a few seconds. Answer the questions in Section B of the data sheet.
4. Empty the jar and rinse with tap water.
5. Place an equal amount of sand and coal in the bottom of the jar. Fill the jar 2/3 full with water. Shake gently to wet all of the sand and coal particles.
6. Add 2 drops of vegetable oil and gently stir with a stir stick for 2 to 4 minutes to allow it to mix with the sand and coal particles.
7. Add 2 drops of detergent and replace the lid. Vigorously shake for 2 to 3 minutes. Stop shaking and let stand for a minute.
8. Open the jar and gently scrape some of the froth onto a filter paper and let it dry.
9. Answer the questions in Section C of the data sheet.

Discussion (Length: 15 minutes)

Discuss the questions and answers on the data sheet. Explain what is happening in each stage of the experiment.

Remind students that in the first step of the experiment, there is not only water in the bottle, but also air. When they shake the bottle, they are mixing the air and water. However, the mixture quickly separates into two phases (liquid and gas) as soon as mixing ceases.

When detergent is added to the air-water mixture and the mixture is shaken, a froth forms at the top surface. Explain that detergent molecules reduce the surface tension and help stabilize the bubbles. Detergent has a hydrophobic end and a hydrophilic end. So, part of the detergent molecule wants to stay in the water, but part of it wants to go into the air. The froth represents the hydrophobic portion of the detergent molecules that are mixed with air.

Vegetable oil is hydrophobic. When vegetable oil is added to a mixture of sand, coal and water, it selectively coats the coal particles making their surface hydrophobic. Because these particles are now hydrophobic, they attach to the air bubbles and are carried to the surface, forming a froth layer.

The large coal particles do not float because they are too big for the bubbles to lift them to the surface. This is why it is important to crush the coal into very small particles prior to froth flotation.

The sand particles settle to the bottom of the jar because they are not hydrophobic, so they do not attach to the air bubbles. If some sand particles get to the froth phase during shaking, they quickly fall back into the water phase when shaking ceases.

In ore processing, the froth layer would be skimmed off the surface and the remainder of the mixture would be disposed of as tailings.

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Floating Coal Data Sheet

A) Mixing Air and Water:

1. What happens when you shake the jar of tap water and air?

2. What happens when you stop shaking the jar?

B) Mixing Detergent, Air and Water:

1. What happens when you shake the jar of water, detergent and air?

2. Why does the froth layer form at the top of the solution?

C) Mixing Sand, Coal, Water, Vegetable Oil and Detergent:

1. What forms at the top surface of the mixture after you stop shaking?

2. Where does the coal go? Why?

3. Where does the sand go? Why?

4. What was on the filter paper?

5. Why don't the large coal particles float? What could be done to make them float?

LEACHING TO SEPARATE METALS FROM ORE

Description

Students will conduct a leaching experiment to extract copper from copper ore.

VOCABULARY:

1. Ore
2. Ion
3. Leaching
4. Solution
5. Solvent
6. Hydrometallurgy
7. Acid
8. Precipitation

MATERIALS:

- *Ground Rules* film
- Finely crushed copper ore
- 100 mL Pyrex beaker or cup
- Plastic spoon
- ½ cup white vinegar
- Hot plate
- Saucepan
- Aluminum wire or foil
- Copper wire
- Safety goggles

Introduction (Length: 15 minutes)

Watch Chapter 2 “Modern Mining” of the *Ground Rules* film. This chapter shows how copper is mined and processed at a large mine site in Chile.

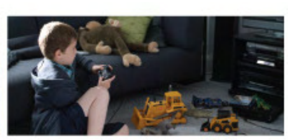
Ask students what leaching is and how it might be used in to process ore.

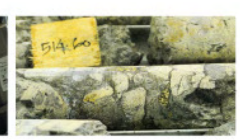
Leaching is one method that can be used to separate some metals from the ore in which they are found. The extraction of metals by use of chemical solutions is called hydrometallurgy. Leaching is one common example of hydrometallurgy.

Leaching is used in approximately 15% of world-wide copper production. Most of these operations are in Chile, Arizona and Australia.

Leaching utilizes a chemical solvent to dissolve or separate (leach) the metal from the ore, forming a solution from which the metal can be collected. The ore is piled onto a surface known as the “leaching pad” and it is then sprayed with the chemical and allowed to dissolve and drain. The concentrate solution can then be processed to recover the desired metal. Sulfuric acid for example, is often used to leach uranium, copper, and zinc ore. An aqueous solution of sodium or potassium cyanide is used to leach some gold and silver ores.





Activity (Length: 20 minutes)

The objective of this activity is to dissolve copper ions and extract them from the solution onto an aluminum wire.

Teacher Preparation:

1. Heat the vinegar in a sauce pan on the hot plate until it is boiling. This should be done in a fume hood prior to the activity.

Activity:

1. Put on safety goggles to avoid splashing vinegar solution into eyes. Preferably complete this activity in a fume hood.
2. Pour approximately 50 mL of hot vinegar into the Pyrex beaker or cup. This is the leaching solution. Note the color of the solution.
3. Add a tablespoon of the crushed copper ore to the Pyrex container (enough to cover the bottom).
4. Note the color of the leaching solution after the addition of the ore. What is happening?
5. Add a piece of aluminum wire or foil (3-4 inches long) with part of the wire in the solution and part hanging over the edge of the beaker.
6. Add a piece of copper wire as a control to demonstrate what happens to copper-containing materials in the reaction.
7. After a few minutes, remove the aluminum from the solution. Did the portion that was in the solution start to change color? If so, why?
8. Replace the aluminum in the solution and check after 30 minutes. Has a color change occurred? What is happening?
9. Leave the materials in the solution for a few days and make daily observations.

Discussion (Length: 10 minutes)

Ask the students to explain what is happening in the beaker. What is vinegar composed of? Vinegar is a weak solution of acetic acid in water. What does the vinegar do to the copper ore? What form is the copper in when it is in solution? Discuss the term “ion”.

What color is the solution? Copper acetate ions have a blue-green color. How does the solution change over time?

Why was the aluminum wire added to the beaker? Did the aluminum wire change color? Why? Some of the copper ions in the solution precipitated onto the aluminum wire.

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

ORE PROCESSING	AGE: 11 TO 13	LENGTH: 1 HR	CURRICULUM: earth science, ore process, magnets

MAGNETIC SEPARATION

Description

Students will explore the properties of magnetite and use a magnet to separate magnetite from sand. They will calculate the grade of magnetite ore in their sample.

VOCABULARY:

1. Magnetite
2. Magnetism
3. Ore grade
4. Magnetic separation

MATERIALS:

- *Ground Rules* film
- Magnetite rock sample
- Non-magnetic rock sample
- Ground magnetite
- Sand
- Strong magnet
- Ziplock bag
- Balance
- Filter paper or paper towel
- Shallow tray or pie plate
- Mineral identification guide or internet access
- Calculators
- Data sheet (provided)

Introduction (Length: 10 minutes)

Watch Chapter 2 “Modern Mining” of the *Ground Rules* film. This chapter shows how copper is mined and processed at a large mine site in Chile.

Review mineral properties. Ask students to name some properties that can be used to identify minerals (e.g, hardness, colour, luster, streak, magnetism).

Explain that after ore is mined, the valuable minerals have to be extracted from the rest of the ore. This can be done in a variety of ways. Explain that in this experiment, students will be using the property of magnetism to separate a magnetic mineral from a crushed ore mixture.

Activity (Length: 40 minutes)

The objectives of this activity are to examine the properties of magnetite, to separate powdered magnetite from sand, and to determine the grade of magnetite.

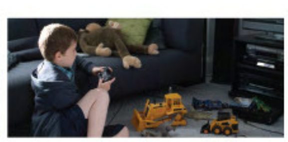
<u>Preparation:</u>

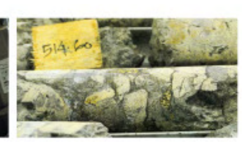
1. Mix together sand and ground magnetite in a container. The amounts don’t have to be measured, but ensure that the mixture includes at least 50% magnetite.

<u>Activity:</u>

1. Divide the class into groups of two.





2. Each group should test the two rock samples with their magnet. Which rock sample is magnetic? Use a mineral identification guide or the internet to determine the name of the magnetic mineral. Provide your answers in Section A of the data sheet.
3. Label a piece of paper towel or a filter paper as “mixture”. Weigh the paper towel/ filter paper on the balance and record the weight in Section B of the data sheet.
4. Add 5 tablespoons of sand and magnetite mixture to the paper towel and record the weight. Subtract the weight of the paper towel from the weight of the mixture and paper towel to get the weight of the mixture. Record in Section B of the data sheet.
5. Carefully dump the contents of the paper towel into a shallow tray or pie plate.
6. Put the magnet into a ziplock bag and seal tightly.
7. Label a piece of paper towel or filter paper as “magnetite”. Weigh the paper towel/ filter paper on the balance and record the weight in Section C of the data sheet.
8. Move the bagged magnet across the top of the sand and magnetite mixture. What happens?
9. Carefully, move the bagged magnet over the paper towel/filter paper. One person should carefully open the ziplock bag. The other person should remove the magnet being careful not to touch the magnetite particles or they will stick to the magnet. Without the magnet in the bag, the particles of magnetite should drop from the outside of the bag onto the paper towel.
10. Repeat steps 8 and 9 until virtually all of the magnetite has been removed from the sample.
11. Weigh the paper towel containing the magnetite and record in Section C of the data sheet. Subtract the weight of the paper towel from the weight of the paper towel containing magnetite to get the weight of the magnetite. Record in Section C of the data sheet.
12. Calculate the “grade” of magnetite as the percentage of magnetite in the mixture. Record in Section C of the data sheet.

Discussion (Length: 10 minutes)

Discuss the questions and answers on the data sheet. Explain what is happening in each stage of the experiment. How useful is magnetic separation? How many minerals have magnetic properties?

Use this example to demonstrate that the separation processes used for extracting valuable minerals can be selected based on the properties of the minerals. In this case, the key property of magnetite is magnetism. Magnetite is mined and used in abrasives, toner, fertilizers, paint pigments and in aggregates for high density concrete. Magnetite is often found in iron-containing ores.

Explain that magnetite is sometimes used to separate pyrite from coal. A slurry of magnetite and water is heavy and allows finer particles of coal to float to the top. The heavier pyrite particles settle to the bottom. A magnetic drum is used to extract the magnetite from the slurry after use.

Why is ore grade important? Discuss the economic and technical considerations involved in deciding whether to mine a deposit. If each of the samples evaluated in the experiment represented an individual mine site, which would be the best site to mine?

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.

Magnetic Separation Data Sheet

A) Magnetic Test:

1. Which rock sample is magnetic?

2. What is the name of the magnetic mineral? How did you determine that?

B) Sand and Magnetite Mixture:

1. Weight of Paper Towel (“Mixture”): ______________________________
2. Weight of Mixture and Paper Towel: ______________________________
3. Weight of Mixture: ______________________________

4. Describe the mixture. What are the dark particles? What are the lighter particles? Which part of the mixture is magnetic?

C) Grade of Magnetite:

1. What happens when you move the bagged magnet across the top of the mixture? Why?

2. Weight of Paper Towel (“Magnetite”): ______________________________
3. Weight of Magnetite and Paper Towel: ______________________________
4. Weight of Magnetite: ______________________________
5. What is the grade (%) of magnetite in your sample? (show the calculation)

GROUND**RULES**

ORE PROCESSING

Ore Processing

AGES 13-15

ELECTROWINNING EXPERIMENT

Description

Students will conduct an experiment to simulate the process of electrowinning that is used in the copper purification process.

VOCABULARY:

1. electrowinning
2. electroplating
3. anode
4. cathode
5. cation
6. anion
7. purification
8. electrolyte

MATERIALS:

- *Ground Rules* film
- Lab coats, safety goggles and gloves
- Copper electroplating solution
- Beaker
- 12 volt A/C power supply
- washer
- stainless steel spatula
- wooden holder for washer and spatula
- 2 alligator clamps to connect power supply
- 500 mL beaker

Introduction (Length: 30 minutes)

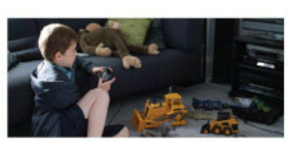
Watch Chapter 2, “Modern Mining” of the *Ground Rules* film. This chapter shows how copper is mined and processed at a large mine site in Chile.

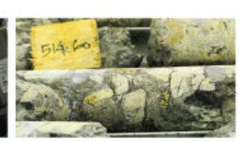
The most common source of copper ore is the mineral chalcopyrite ($CuFeS_2$). Approximately 50% of copper production throughout the world comes from this mineral.

Review the steps involved in processing copper ore, as mentioned in the film: crushing, extraction, concentration, smelting and purification (electrowinning). First the ore is crushed into a fine powder to increase the surface area for further processing. Next, the copper is extracted and concentrated by froth flotation in which ground ore is mixed with reagents in an aerated tank filled with water. The hydrophobic copper sulfide particles attach to the air bubbles and float to the surface where they form a froth that is skimmed off (see Lesson Plan on Copper Extraction for more details on this process). Next, the copper concentrate is smelted at high temperatures to form a liquid called copper matte, which is further purified by the removal of sulfur as sulfur dioxide, resulting in an end product called “copper blister” which is approximately 98-99% copper. Finally, in the purification process, copper is refined using a process called electrowinning. Explain that in this activity, they will be exploring the process of electrowinning.

Electrowinning is based on the process of electroplating. Ask the students if they know what electroplating is. Review the terms anion, cation, anode and cathode. Explain that electroplating involves movement of positively charged ions (cations) from an anode through a salt solution. The cations in the salt solution are then attracted to the cathode, where they deposit onto it in metallic form.





The Electrowinning Process for Copper Purification:
The copper blister is put into an anode furnace (i.e., a furnace that makes anodes) to burn off most of the remaining oxygen, usually done by blowing natural gas through the molten copper oxide. The anodes from the furnace are then placed into an aqueous solution of copper sulfate and sulfuric acid (electrolyte solution). The cathodes consist of thin sheets of pure copper. When connected to a power supply, the copper and other metals dissolve from the anode. The copper ions migrate through the electrolyte solution and plate out onto the cathode. The impurities (such as silver, gold, selenium and tellurium) settle to the bottom.

The chemical reactions in the electowinning process are:

Anode: $Cu_{(anode)} \rightarrow Cu^{2+}{}_{(aqueous)} + 2e^-$

Cathode: $Cu^{2+}{}_{(aqueous)} + 2e^- \rightarrow Cu_{(cathode)}$

The copper (at the cathode) is the final product of copper processing. It is usually prepared in sheets that are 1 cm thick and approximately 1 meter square, weighing approximately 200 pounds (as shown on the film).

Activity (Length: 30 minutes)

The objective of this activity is to simulate the electrowinning process involved in purifying copper. This activity can be done as a class demonstration or in student groups.

1. Put on a lab coat, safety goggles and gloves.
2. Attach one end of an alligator clamp to the spatula (anode). Attach one end of another alligator clamp to the washer (cathode).
3. Thread the spatula and washer through the wooden holder and place the holder horizontally on top of the beaker (as shown below).
4. Fill the beaker with enough electroplating solution to cover the washer.
5. Attach the other ends of the alligator cables to the power supply. Turn on the power (3 volts is usually sufficient) and observe what happens. Copper plating should begin to occur in a few seconds.
6. Leave the power on for the duration of the class and observe the plating on the washer at the end of class.

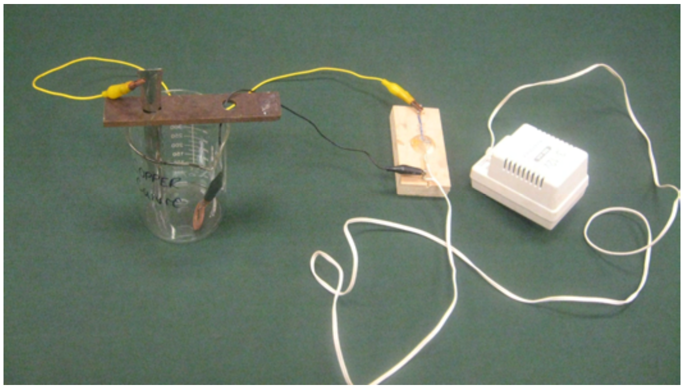


Figure 1 Experimental Setup

Discussion (Length: 15 minutes)

Ask the students to explain what happened in the experiment. How does this experiment demonstrate the process of electrowinning used in the copper purification process? Why is it necessary to remove the impurities from the copper using this process (i.e., why is 98-99% copper purity insufficient)?

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.

EXTRACTING COPPER FROM SULFIDE ORES

Description

Students will extract copper from sulfide ores by simulating the crushing, milling and flotation processes. They will discuss the remaining steps involved in copper production.

VOCABULARY:

1. Crushing
2. Milling
3. Froth Flotation
4. Sulfide ores
5. Copper
6. Slurry
7. Hydrophobic
8. Hydrophilic
9. Surfactant
10. Tailings
11. Waste rock

MATERIALS:

- *Ground Rules* film
- Hammer
- Large container
- Old socks
- Safety glasses
- Sulfide ore
- Plastic container (shoebox size), water
- 4 plastic cups (8 oz), plastic jar with lid
- Steel shot (1/2 - 1 cm; 1/4 - 3/8 inch)
- Wire mesh screen (1/2 cm; 1/4 inch)
- Small bottle of bubble bath liquid
- 2 index cards, laminated
- Drinking straws, teaspoons, paper towels

Introduction (Length: 15 minutes)

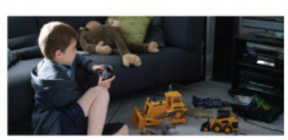
Watch Chapter 2 “Modern Mining” of the *Ground Rules* film. This chapter shows how copper is mined and processed at a large mine site in Chile.

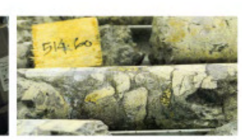
The most common source of copper ore is the mineral chalcopyrite ($CuFeS_2$). Approximately 50% of copper is produced from chalcopyrite.

Pass around a piece of sulfide ore. Tell the class there is copper in the ore. Ask them how they think they could liberate the copper particles from the ore? Discuss the crushing process used in mining to extract valuable minerals from waste rock. The crushing process involves breaking up the ore into small pieces (up to 20 cm or 8 inches in diameter), so it can be handled effectively in the next phase of ore processing: milling.

Ask the class if they know what happens in the milling process. The milling process breaks the ore pieces into fine particles. In milling, the crushed ore and liquid are put into large rotating drums called mills. There are a variety of different types of mills. Typically, steel balls or rods are added to the mills. Why? The steel collides with the ore and assists in breaking it into smaller pieces. At the end of the milling process, a slurry of fine particles and water is produced. In the final step of the milling process, chemicals are added to the slurry to prepare the copper minerals for separation from the powdered rock.





Ask the class how they think the copper can be separated from the rest of the slurry. In the next phase of ore processing, copper minerals can be removed by flotation. A detergent-like substance called a frother and chemical reagents called collectors are added to the slurry. The collectors adhere only to the copper minerals, not the other particles of rock. When air is forced through the slurry, the mixture attaches to the air bubbles and floats to the top of the liquid. The copper then ends up in the froth which floats on the surface of the tank and is skimmed off the top. The substance that is skimmed off the top is call “copper concentrate”. The copper concentrate is cleaned, dewatered, filtered, dried and shipped to a smelter.

Explain that the students will be conducting an experiment to simulate the processes of crushing, milling and froth flotation.

Figure 1 Froth Flotation Tank

Activity (Length: 45 minutes)

The objective of this activity is to extract copper from sulfide ore by simulating the crushing, milling and flotation processes.

Divide the class into groups of 3 students.

Step 1: Crushing Process

1. Put on safety glasses to protect eyes from flying bits of rock. Keep them on at all times during this activity.
2. Place a few pieces of sulfide ore inside an old sock.
3. Place the sock containing the sulfide ore pieces on a hard, flat surface.
4. Use a hammer to crush the sulfide ore into quarter-sized and smaller pieces.
5. Place all of the pieces of ore that are quarter-sized or smaller into the large container.
6. Answer the question on the data sheet under "Crushing Process".

Step 2: Milling Process

1. Using a marker, label three 8 oz plastic cups as 1, 2 and 3.
2. Fill the jar approximately 1/3 full with crushed sulfide ore and steel shot. Keep a few pieces of the ore and steel shot aside.
3. Add water to the jar until the ore and shot are submerged by approximately 1 cm. Screw the lid tightly onto the jar.
4. Wrap the jar in the towel and shake for 2 minutes.
5. Place the wire mesh screen over the shoebox sized container. Pour the mixture from the jar onto the screen.
6. Pour the liquid from the shoebox-sized container into the 8 oz plastic cup labeled "1". Check to make sure you have gotten all of the fine material out of the container. Observe the ore, the steel shot and the water. Compare the ore and steel shot to the pieces set aside and record observations on the data table in the space labeled "Trial 1".
7. Return oversize pieces of ore to the jar and repeat steps 3 to 6 two more times. Pour the slurry from Trials 2 and 3 into the plastic cups labeled "2" and "3", respectively.
8. After each trial, compare the reserved steel shot, the ore and the water in each cup. In the data table on the milling process section of the data sheet, record any noticeable changes in the size and shape of the ore and steel shot and any changes in the water.
9. Set aside all three cups of slurry for the Flotation Process.
10. Separate remaining large pieces of ore from the steel shot. Place both materials on a paper towel to dry.
11. When all materials are dry, return them to the original containers.
12. Clean the jar and shoebox container being careful not to wash any of the remaining slurry into a drain.
13. Answer the questions in the "Milling Process" section of the data sheet.

Step 3: Flotation Process

1. Each group should designate one student as the "recorder" who will record observations for the group and two students as the "experimenters" who will conduct the experiment.
2. Set aside slurry cup "1" from the Milling Process for observation.
3. Add 4 to 6 teaspoons of the bubble bath liquid into slurry cup "2" and stir the contents.
4. Place one straw each into slurry cups "2" and "3". The two experimenters in each group should blow gently but steadily through each straw for 30 seconds.
5. Use the index cards to scrape any bubbles off the top of the slurry in each cup and place them on separate paper towels to dry. Label the deposited bubbles as "Trial 1".
6. The recorder of each group should record the group's observations for "Trial 1" on the data sheet while the experimenters should proceed immediately to Step 7. Don't allow the cups to "rest" between trials.
7. The experimenters should begin "Trial 2" by repeating steps 4 to 6. Then repeat again for "Trial 3" and "Trial 4". After each trial, the recorder should record the group's observations on the data sheet.
8. Dispose of the slurries by placing them in a garbage receptacle lined with a strong plastic bag. Do not pour slurry into a drain.

9. Answer the questions in the “Flotation Process” section of the data sheet.

Discussion (Length: 30 minutes)

Review the observations made by each of the groups and the answers to the questions on the data sheet.

What happens to the remaining rock fragments left behind at the bottom of the flotation tank? This mixture, known as tailings, is typically pumped to a tailings impoundment where the water is removed and recycled back into the flotation process. The remaining waste rock must be stockpiled and eventually incorporated into the reclaimed landscape after mining operations have ceased.

Review the process of froth flotation in more detail. Why are the copper particles collected on the bubbles? Why does the addition of soap help separate the copper particles? What is the purpose of the air? Review the terms hydrophobic and hydrophilic. The soap is a surfactant which has a hydrophobic end and a hydrophilic end. In actual copper flotation processes, a specific surfactant is added that binds to the copper making it hydrophobic. The remainder of the solution remains hydrophilic. The hydrophobic mineral particles then attach to the air bubbles and float to the surface.

Briefly discuss the next steps involved in processing copper. After flotation, the copper concentrate contains only 20 to 40% pure copper. The next step in the process is to convert the copper concentration to 99% pure copper. This is accomplished in the smelting process where high temperatures are used to roast the concentrate, smelt it in a furnace and oxidize and reduce the molten material to progressively remove the unwanted elements, such as sulfur, iron, silicon and oxygen. Relatively pure copper (99%) is left behind. The final step in the process is called electro-refining or electro-winning. In this process, copper is purified through electrolysis. An electric current is passed through the material which separates the copper ions from the impurities.

Extracting Copper from Sulfide Ore Data Sheet

Crushing Process:

Was it easy or difficult to crush the sulfide ore into small pieces?

Milling Process:

Trial	Changes in Sulfide Ore	Changes in Steel Shot	Changes in Water
1			
2			
3			

What does the jar represent?

What is the purpose of the steel shot?

What is the purpose of the screen?

Why is the milling process necessary?

Flotation Process:

Record the behavior of each slurry cup after each trial in the following table:

Trial	Slurry Cup 1 (slurry only; control)	Slurry Cup 2 (slurry with bubble liquid and air)	Slurry Cup 3 (slurry with air)
1			
2			
3			
4			

What was observed collecting onto the bubbles?

What was the purpose of injecting air into the slurry cups? What happened to the ore in the cups when air was added? Why?

Was there a difference in what was collected on the bubbles from Slurry Cups 2 and 3?

Was all of the copper in the slurry collected after 4 trials? Is this “pure” copper?

ORE PROCESSING | AGE: 13 TO 15 | LENGTH: 1.5HR | CURRICULUM: earth science, ore process, mixtures

FLOATING COAL

Description

Students will explore the process of froth flotation to separate coal from a mixture of coal and sand. They will learn about how coal is processed.

VOCABULARY:

1. Froth flotation
2. Hydrophobic
3. Hydrophilic
4. Surface tension
5. Slurry
6. Concentrate
7. Tailings
8. Mixtures

MATERIALS:

- *Ground Rules* film
- Clear glass jar
- Liquid detergent and eye dropper
- Vegetable oil and eye dropper
- Stirring rod
- Silica sand (approx. same size as coal particles)
- Powdered coal, with some larger flakes
- Filter paper (can use coffee filters)
- Data sheet (provided)
- Resource books or internet access

Introduction (Length: 15 minutes)

Watch Chapter 8 “Reclamation” of the *Ground Rules* film. This chapter shows how coal is mined at a mine site in the United States.

Pass around a mixture of sand and coal. Ask the students how they think they could extract the coal from the sand. Suggest the idea of using a sieve to separate the particles. Ask the students if that would work. Explain that a sieve would not work because some of the sand particles are the same size as the coal particles.

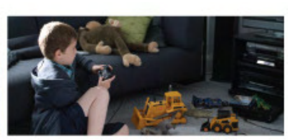
Explain that froth flotation is a process that is used to remove coal from the sand. This process can also be used to separate valuable metals from ore (see Lesson plan on copper extraction for more details). Explain that the students will be conducting an experiment to separate coal from a coal-sand mixture using the process of froth flotation.

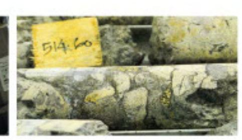
Activity I (Length: 30 minutes)

The objective of this activity is to separate coal from a coal-sand mixture using the process of froth flotation.

1. Divide the class into groups of two.
2. Have each group fill the glass jar approximately 2/3 full with tap water, secure the lid and shake vigorously. Stop shaking and let stand for a few seconds. Answer the questions in Section A of the data sheet.





3. Add 2 drops of detergent to the tap water, secure the lid and shake vigorously. Stop shaking and let stand for a few seconds. Answer the questions in Section B of the data sheet.
4. Empty the jar and rinse with tap water.
5. Place an equal amount of sand and coal in the bottom of the jar. Fill the jar 2/3 full with water. Shake gently to wet all of the sand and coal particles.
6. Add 2 drops of vegetable oil and gently stir with a stir stick for 2 to 4 minutes to allow it to mix with the sand and coal particles.
7. Add 2 drops of detergent and replace the lid. Vigorously shake for 2 to 3 minutes. Stop shaking and let stand for a minute.
8. Open the jar and gently scrape some of the froth onto a filter paper and let it dry.
9. Answer the questions in Section C of the data sheet.

Activity II (Length: 30 minutes)

The objective of this activity is to learn how coal is processed for use as fuel and for use as coke in the steel making industry.

Using resource books or the internet, answer the following questions:

1. What are the major uses of coal?
2. How is coal processed for use as fuel?
3. How is coal processed to make coke? What is coke used for?
4. How much of your country's energy comes from burning coal?

Discussion (Length: 15 minutes)

<u>Activity I:</u>
Discuss the questions and answers on the data sheet. Explain what is happening in each stage of the experiment.

Remind students that in the first step of the experiment, there is not only water in the bottle, but also air. When they shake the bottle, they are mixing the air and water. However, the mixture quickly separates into two phases (liquid and gas) as soon as mixing ceases.

When detergent is added to the air-water mixture and the mixture is shaken, a froth forms at the top surface. Explain that detergent molecules reduce the surface tension and help stabilize the bubbles. Detergent has a hydrophobic end and a hydrophilic end. So, part of the detergent molecule wants to stay in the water, but part of it wants to go into the air. The froth represents the hydrophobic portion of the detergent molecules that are mixed with air.

Vegetable oil is hydrophobic. When vegetable oil is added to a mixture of sand, coal and water, it selectively coats the coal particles making their surface hydrophobic. Because these particles are now hydrophobic, they attach to the air bubbles and are carried to the surface, forming a froth layer.

The large coal particles do not float because they are too big for the bubbles to lift them to the surface. This is why it is important to crush the coal into very small particles prior to froth flotation.

The sand particles settle to the bottom of the jar because they are not hydrophobic, so they do not attach to the air bubbles. If some sand particles get to the froth phase during shaking, they quickly fall back into the water phase when shaking ceases.

In ore processing, the froth layer would be skimmed off the surface and the remainder of the mixture would be disposed of as tailings.

Activity II:
Coal that will be used as fuel does not require a lot of processing prior to use. However, impurities must be removed and coal is usually graded into various size fractions. Crushing, followed by flotation or screening techniques can be used to separate size fractions.

Coal is processed into coke for use in steel production. To make coke, the volatile constituents of the coal are driven off by baking in an anaerobic oven at high temperatures. The remaining ash is coke. Coke can also be used as a fuel and as a reducing agent in the iron smelting process.

Discuss the reliance of your country on coal as an energy source.

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.

Floating Coal Data Sheet

A) Mixing Air and Water:

1. What happens when you shake the jar of tap water and air?

2. What happens when you stop shaking them?

B) Mixing Detergent, Air and Water:

1. What happens when you shake the jar of water, detergent and air?

2. Why does the froth layer form at the top of the solution?

C) Mixing Sand, Coal, Water, Vegetable Oil and Detergent:

1. What forms at the top surface of the mixture?

2. Where does the coal go? Why?

3. Where does the sand go? Why?

4. What was on the filter paper?

5. Why don't the large coal particles float? What could be done to make them float?

LEACHING TO SEPARATE METALS FROM ORE

Description

Students will conduct a leaching experiment to extract copper from copper ore. They will also experiment with materials containing iron and zinc.

VOCABULARY:

1. Ore
2. Ion
3. Leaching
4. Solution
5. Solvent
6. Hydrometallurgy
7. Acid
8. Precipitation

MATERIALS:

- *Ground Rules* film
- Finely crushed copper ore
- 100 mL Pyrex beaker or cup
- Plastic spoon
- ½ cup white vinegar
- Hot plate
- Saucepan
- Aluminum wire or aluminum foil
- Steel nail
- Zinc coated nail
- Copper wire
- Safety goggles

Introduction (Length: 15 minutes)

Watch Chapter 2 "Modern Mining" of the *Ground Rules* film. This chapter shows how copper is mined and processed at a large mine site in Chile.

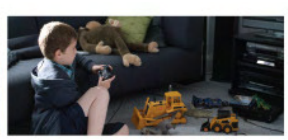
Ask students what leaching is and how it might be used in to process ore.

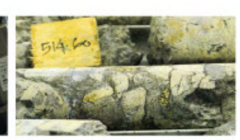
Leaching is one method that can be used to separate some metals from the ore in which they are found. The extraction of metals by use of chemical solutions is called hydrometallurgy. Leaching is one common example of hydrometallurgy.

Leaching is used in approximately 15% of world-wide copper production. Most of these operations are in Chile, Arizona and Australia.

Leaching utilizes a chemical solvent to dissolve or separate (leach) the metal from the ore, forming a solution from which the metal can be collected. The ore is piled onto a surface known as the "leaching pad" and it is then sprayed with the chemical and allowed to dissolve and drain. The concentrate solution can then be processed to recover the desired metal. Sulfuric acid for example, is often used to leach uranium, copper, and zinc ore. An aqueous solution of sodium or potassium cyanide is used to leach some gold and silver ores.





Activity I (Length: 20 minutes, plus follow-up)

The objective of this activity is to dissolve copper ions and extract them from the solution onto an aluminum wire.

Teacher Preparation:
1. Heat the vinegar in a sauce pan on the hot plate until it is boiling. This should be done in a fume hood prior to the activity.

Activity:
1. Put on safety goggles to avoid splashing vinegar solution into eyes. Preferably complete this activity in a fume hood.
2. Pour approximately 50 mL of hot vinegar into the Pyrex beaker or cup. This is the leaching solution. Note the color of the solution.
3. Add a tablespoon of the crushed copper ore to the Pyrex container (enough to cover the bottom).
4. Note the color of the leaching solution after the addition of the ore. What is happening?
5. Add a piece of aluminum wire or foil (3-4 inches long) with part of the wire in the solution and part hanging over the edge of the beaker.
6. Add a piece of copper wire as a control to demonstrate what happens to copper-containing materials in the reaction.
7. After a few minutes, remove the aluminum from the solution. Did the portion that was in the solution start to change color? If so, why?
8. Replace the aluminum in the solution and check after 30 minutes. Has a color change occurred? What is happening?
9. Leave the materials in the solution for a few days and make daily observations.

Activity II (Length: 10 minutes, plus follow-up)

The objective of this activity is to observe what happens to materials containing iron and zinc when placed in a leaching solution.

1. Put on safety goggles to avoid splashing vinegar solution into eyes. Preferably complete this activity in a fume hood.
2. Prepare another two beakers with 50 mL of hot vinegar solution.
3. Add a steel nail to one beaker and a zinc coated nail to the other, with a portion in the solution and a portion outside the solution. What happens?
4. Leave the materials in the solution for a few days and make daily observations.

Discussion (Length: 15 minutes)

Activity I:
Ask the students to explain what is happening in the beaker. What is vinegar composed of? Vinegar is a weak solution of acetic acid in water. What does the vinegar do to the copper ore? What form is the copper in when it is in solution? Discuss the term “ion”.

What color is the solution? Copper acetate ions have a blue-green color. How does the solution change over time?

Why was the aluminum wire added to the beaker? Did the aluminum wire change color? Why? Some of the copper ions in the solution precipitated onto the aluminum wire.

Why didn't the aluminum leach from the wire? When aluminum is exposed to oxygen, it forms a thin layer of aluminum oxide on its surface which is relatively resistant to the corrosive effects of acetic acid.

Activity II:
What happened to the steel nail (containing iron) and the zinc coated nail? Iron and zinc are easily corroded by acetic acid.

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.

MAGNETIC SEPARATION

Description

Students will explore the properties of magnetite and use a magnet to separate magnetite from sand. They will calculate the grade of magnetite ore in their sample. They will research the properties, mining areas and uses of magnetite.

VOCABULARY:

1. Magnetite
2. Magnetism
3. Ore grade
4. Magnetic separation

MATERIALS:

- *Ground Rules* film
- Magnetite rock sample
- Non-magnetic rock sample
- Ground magnetite
- Sand
- Strong magnet
- Ziplock bag
- Balance
- Filter paper or paper towel
- Shallow tray or pie plate
- Mineral identification guide or internet access
- Calculators
- Data sheet (provided)

Introduction (Length: 10 minutes)

Watch Chapter 2 “Modern Mining” of the *Ground Rules* film. This chapter shows how copper is mined and processed at a large mine site in Chile.

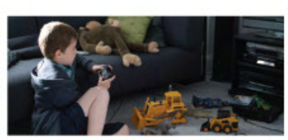
Review mineral properties. Ask students to name some properties that can be used to identify minerals (e.g, hardness, colour, luster, streak, magnetism).

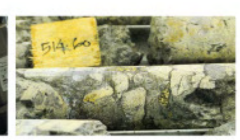
Explain that after ore is mined, the valuable minerals have to be extracted from the rest of the ore. This can be done in a variety of ways. Explain that in this experiment, students will be using the property of magnetism to separate a magnetic mineral from an ore mixture.

Activity I (Length: 30 minutes)

The objectives of this activity are to examine the properties of magnetite, to separate powdered magnetite from sand, and to determine the grade of magnetite.





Preparation:

1. Mix together sand and ground magnetite in a container. The amounts don't have to be measured, but ensure that the mixture includes at least 50% magnetite.

Activity:

1. Divide the class into groups of two.
2. Each group should test the two rock samples with their magnet. Which rock sample is magnetic? Use a mineral identification guide or the internet to determine the name of the magnetic mineral. Provide your answers in Section A of the data sheet.
3. Label a piece of paper towel or a filter paper as "mixture". Weigh the paper towel/ filter paper on the balance and record the weight in Section B of the data sheet.
4. Add 5 tablespoons of sand and magnetite mixture to the paper towel and record the weight. Subtract the weight of the paper towel from the weight of the mixture and paper towel to get the weight of the mixture. Record in Section B of the data sheet.
5. Carefully dump the contents of the paper towel into a shallow tray or pie plate.
6. Put the magnet into a ziplock bag and seal tightly.
7. Label a piece of paper towel or filter paper as "magnetite". Weigh the paper towel/ filter paper on the balance and record the weight in Section C of the data sheet.
8. Move the bagged magnet across the top of the sand and magnetite mixture. What happens?
9. Carefully, move the bagged magnet over the paper towel/filter paper. One person should carefully open the ziplock bag. The other person should remove the magnet being careful not to touch the magnetite particles or they will stick to the magnet. Without the magnet in the bag, the particles of magnetite should drop from the outside of the bag onto the paper towel.
10. Repeat steps 8 and 9 until virtually all of the magnetite has been removed from the sample.
11. Weigh the paper towel containing the magnetite and record in Section C of the data sheet. Subtract the weight of the paper towel from the weight of the paper towel containing magnetite to get the weight of the magnetite. Record in Section C of the data sheet.
12. Calculate the "grade" of magnetite as the percentage of magnetite in the mixture. Record in Section C of the data sheet.

Activity II (Length: 30 minutes)

The objective of this activity is to research the properties, mining areas and uses of magnetite.

Using resource books or the internet, answer the following questions:

1. Name three properties of magnetite other than magnetism.
2. What type of rocks can magnetite be found in?
3. How and where is magnetite mined?
4. Describe the process whereby magnetite is used to extract coal from pyrite-rich ore. How is the property of magnetism used in this process?
5. What types of products contain magnetite? What properties of magnetite make it useful for these products?
6. What mineral is magnetite often found in association with?

Discussion (Length: 20 minutes)

Activity I:
Discuss the questions and answers on the data sheet. Explain what is happening in each stage of the experiment. How useful is magnetic separation? How many minerals have magnetic properties?

Why is ore grade important? Discuss the economic and technical considerations involved in deciding whether to mine a deposit. If each of the samples evaluated in the experiment represented an individual mine site, which would be the best site to mine?

Activity II:
Discuss the answers to the questions. Magnetite is found in igneous, metamorphic and sedimentary rocks. It is mined in Australia, Switzerland, South Africa and the United States. It is used in abrasives, toner, fertilizers, paint pigments, and in aggregates for high density concrete. Magnetite is often found in iron-containing ores.

Explain that magnetite is sometimes used to separate pyrite from coal. A slurry of magnetite and water is heavy and allows finer particles of coal to float to the top. The heavier pyrite particles settle to the bottom. A magnetic drum is used to extract the magnetite from the slurry after use.

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.

Magnetic Separation Data Sheet

A) Magnetic Test:

1. Which rock sample is magnetic?

2. What is the name of the magnetic mineral? How did you determine that?

B) Sand and Magnetite Mixture:

1. Weight of Paper Towel (“Mixture”): ______________________________
2. Weight of Mixture and Paper Towel: ______________________________
3. Weight of Mixture: ______________________________

4. Describe the mixture. What are the dark particles? What are the lighter particles? Which part of the mixture is magnetic?

C) Grade of Magnetite:

1. What happens when you move the bagged magnet across the top of the mixture? Why?

2. Weight of Paper Towel (“Magnetite”): ______________________________
3. Weight of Magnetite and Paper Towel: ______________________________
4. Weight of Magnetite: ______________________________
5. What is the grade (%) of magnetite in your sample? (show the calculation)

GROUND**RULES**

ORE PROCESSING

Ore Processing

AGES 15-18

ELECTROWINNING EXPERIMENT

Description

Students will conduct an experiment to simulate the process of electrowinning that is used in the copper purification process. They will also discuss the by-products of ore processing.

VOCABULARY:

1. electrowinning
2. electroplating
3. anode
4. cathode
5. cation
6. anion
7. purification
8. electrolyte
9. by-product

MATERIALS:

- *Ground Rules* film
- Lab coats, safety goggles and gloves
- Copper electroplating solution
- Beaker
- 12 volt A/C power supply
- washer
- stainless steel spatula
- wooden holder for washer and spatula
- 2 alligator clamps to connect power supply
- 500 mL beaker

Introduction (Length: 30 minutes)

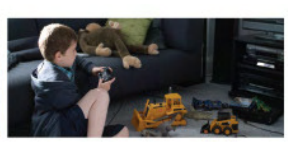
Watch Chapter 2, "Modern Mining" of the *Ground Rules* film. This chapter shows how copper is mined and processed at a large mine site in Chile.

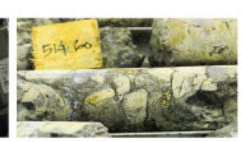
The most common source of copper ore is the mineral chalcopyrite ($CuFeS_2$). Approximately 50% of copper production throughout the world comes from this mineral.

Review the steps involved in processing copper ore, as mentioned in the film: crushing, extraction, concentration, smelting and purification (electrowinning). First the ore is crushed into a fine powder to increase the surface area for further processing. Next, the copper is extracted and concentrated by froth flotation in which ground ore is mixed with reagents in an aerated tank filled with water. The hydrophobic copper sulfide particles attach to the air bubbles and float to the surface where they form a froth that is skimmed off (see Lesson Plan on Copper Extraction for more details on this process). Next, the copper concentrate is smelted at high temperatures to form a liquid called copper matte, which is further purified by the removal of sulfur as sulfur dioxide, resulting in an end product called "copper blister" which is approximately 98-99% copper. Finally, in the purification process, copper is refined using a process called electrowinning. Explain that in this activity, they will be exploring the process of electrowinning.

Electrowinning is based on the process of electroplating. Ask the students if they know what electroplating is. Review the terms anion, cation, anode and cathode. Explain that electroplating involves movement of positively charged ions (cations) from an anode through a salt solution. The cations in the salt solution are then attracted to the cathode, where they deposit onto it in metallic form.





<u>The Electrowinning Process for Copper Purification:</u>
The copper blister is put into an anode furnace (i.e., a furnace that makes anodes) to burn off most of the remaining oxygen, usually done by blowing natural gas through the molten copper oxide. The anodes from the furnace are then placed into an aqueous solution of copper sulfate and sulfuric acid (electrolyte solution). The cathodes consist of thin sheets of pure copper. When connected to a power supply, the copper and other metals dissolve from the anode. The copper ions migrate through the electrolyte solution and plate out onto the cathode. The impurities (such as silver, gold, selenium and tellurium) settle to the bottom.

The chemical reactions in the electowinning process are:

Anode: $Cu_{(anode)} \rightarrow Cu^{2+}{}_{(aqueous)} + 2e-$

Cathode: $Cu^{2+}{}_{(aqueous)} + 2e- \rightarrow Cu_{(cathode)}$

The copper (at the cathode) is the final product of copper processing. It is usually prepared in sheets that are 1 cm thick and approximately 1 meter square, weighing approximately 200 pounds (as shown on the film).

Activity (Length: 30 minutes)

The objective of this activity is to simulate the electrowinning process involved in purifying copper. This activity can be done as a class demonstration or in student groups.

1. Put on lab coat, safety goggles and gloves.
2. Attach one end of an alligator clamp to the spatula (anode). Attach one end of another alligator clamp to the washer (cathode).
3. Thread the spatula and washer through the wooden holder and place horizontally on top of the beaker (as shown below).
4. Fill the beaker approximately with enough electroplating solution to cover the washer.
5. Attach the other ends of the alligator cables to the power supply. Turn on the power (3 volts is usually sufficient) and observe what happens. Copper plating should begin to occur in a few seconds.
6. Leave the power on for the duration of the class and observe the plating on the washer at the end of class.

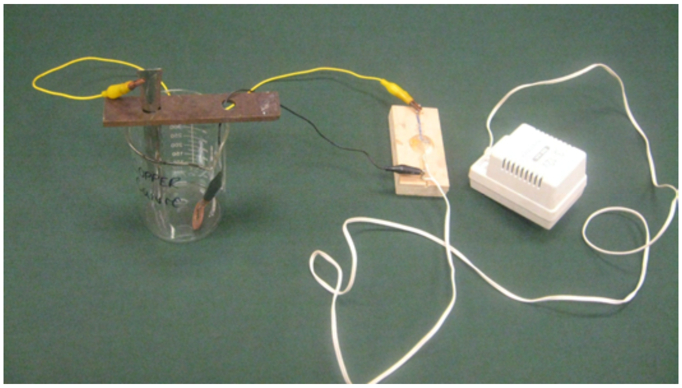


Figure 1 Experimental Setup

Discussion (Length: 30 minutes)

Ask the students to explain what happened in the experiment. How does this experiment demonstrate the process of electrowinning used in the copper purification process? Why is it necessary to remove the impurities from the copper using this process (i.e., why is 98-99% copper purity insufficient)?

What are the waste products produced at each step in copper ore processing? The by-product of extraction is tailings. The by-products of smelting are sulfur dioxide gas and slag. The by-product of electrowinning is anode mud which may include a variety of metals (silver, gold are the most valuable). The valuable metals may be extracted from the anode mud and form a secondary saleable product.

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.

EXTRACTING COPPER FROM SULFIDE ORES

Description

Students will extract copper from sulfide ores by simulating the crushing, milling and flotation processes. In the second activity, they will research the remaining steps in the production of copper (smelting and electrowinning).

VOCABULARY:

1. Crushing
2. Milling
3. Froth Flotation
4. Sulfide ores
5. Copper
6. Slurry
7. Hydrophobic
8. Hydrophilic
9. Surfactant
10. Tailings
11. Waste rock

MATERIALS:

- *Ground Rules* film
- Hammer
- Large container
- Old socks
- Safety glasses
- Sulfide ore
- Plastic container (shoebox size), water
- 4 plastic cups (8 oz), plastic jar with lid
- Steel shot (1/2 - 1 cm; 1/4 - 3/8 inch)
- Wire mesh screen (1/2 cm; 1/4 inch)
- Small bottle of bubble bath liquid
- 2 index cards, laminated
- Drinking straws, teaspoons, paper towels
- Resource books or internet access

Introduction (Length: 15 minutes)

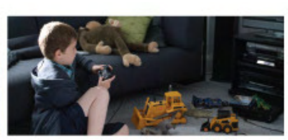
Watch Chapter 2 “Modern Mining” of the *Ground Rules* film. This chapter shows how copper is mined and processed at a large mine site in Chile.

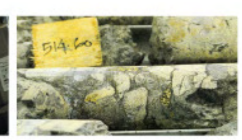
The most common source of copper ore is the mineral chalcopyrite ($CuFeS_2$). Approximately 50% of copper is produced from chalcopyrite.

Pass around a piece of sulfide ore. Tell the class there is copper in the ore. Ask them how they think they could liberate the copper particles from the ore? Discuss the crushing process used in mining to extract valuable minerals from waste rock. The crushing process involves breaking up the ore into small pieces (up to 20 cm or 8 inches in diameter), so it can be handled effectively in the next phase of ore processing: milling.

Ask the class if they know what happens in the milling process. The milling process breaks the ore pieces into fine particles. In milling, the crushed ore and liquid are put into large rotating drums called mills. There are a variety of different types of mills. Typically, steel balls or rods are added to the mills. Why? The steel collides with the ore and assists in breaking it into smaller pieces. At the end of the milling process, a slurry of fine particles and water is produced. In the final step of the milling process, chemicals are added to the slurry to prepare the copper minerals for separation from the powdered rock.





Ask the class how they think the copper can be separated from the rest of the slurry. In the next phase of ore processing, copper minerals can be removed by flotation. A detergent-like substance called a frother and chemical reagents called collectors are added to the slurry. The collectors adhere only to the copper minerals, not the other particles of rock. When air is forced through the slurry, the mixture attaches to the air bubbles and floats to the top of the liquid. The copper then ends up in the froth which floats on the surface of the tank and is skimmed off the top. The substance that is skimmed off the top is call "copper concentrate". The copper concentrate is cleaned, dewatered, filtered, dried and shipped to a smelter.

Explain that the students will be conducting an experiment to simulate the processes of crushing, milling and froth flotation.

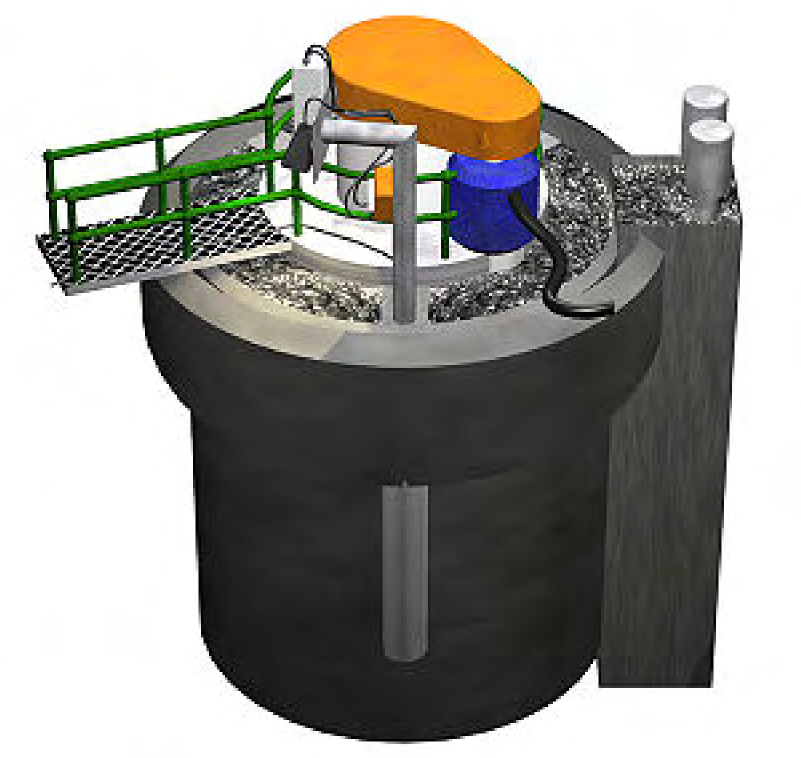


Figure 1 Froth Flotation Tank

Activity I (Length: 45 minutes)

The objective of this activity is to extract copper from sulfide ore by simulating the crushing, milling and flotation processes.

Divide the class into groups of 3 students.

Step 1: Crushing Process

1. Put on safety glasses to protect eyes from flying bits of rock. Keep them on at all times during this activity.
2. Place a few pieces of sulfide ore inside an old sock.
3. Place the sock containing the sulfide ore pieces on a hard, flat surface.
4. Use a hammer to crush the sulfide ore into quarter-sized and smaller pieces.
5. Place all of the pieces of ore that are quarter-sized or smaller into the large container.
6. Answer the question on the data sheet under “Crushing Process”.

Step 2: Milling Process

1. Using a marker, label three 8 oz plastic cups as 1, 2 and 3.
2. Fill the jar approximately 1/3 full with crushed sulfide ore and steel shot. Keep a few pieces of the ore and steel shot aside.
3. Add water to the jar until the ore and shot are submerged by approximately 1 cm. Screw the lid tightly onto the jar.
4. Wrap the jar in the towel and shake for 2 minutes.
5. Place the wire mesh screen over the shoebox sized container. Pour the mixture from the jar onto the screen.
6. Pour the liquid from the shoebox-sized container into the 8 oz plastic cup labeled “1”. Check to make sure you have gotten all of the fine material out of the container. Observe the ore, the steel shot and the water. Compare the ore and steel shot to the pieces set aside and record observations on the data table in the space labeled “Trial 1”.
7. Return oversize pieces of ore to the jar and repeat steps 3 to 6 two more times. Pour the slurry from Trials 2 and 3 into the plastic cups labeled “2” and “3”, respectively.
8. After each trial, compare the reserved steel shot, the ore and the water in each cup. In the data table on the milling process section of the data sheet, record any noticeable changes in the size and shape of the ore and steel shot and any changes in the water.
9. Set aside all three cups of slurry for the Flotation Process.
10. Separate remaining large pieces of ore from the steel shot. Place both materials on a paper towel to dry.
11. When all materials are dry, return them to the original containers.
12. Clean the jar and shoebox container being careful not to wash any of the remaining slurry into a drain.
13. Answer the questions in the “Milling Process” section of the data sheet.

Step 3: Flotation Process

1. Each group should designate one student as the “recorder” who will record observations for the group and two students as the “experimenters” who will conduct the experiment.
2. Set aside slurry cup “1” from the Milling Process for observation.
3. Add 4 to 6 teaspoons of the bubble bath liquid into slurry cup “2” and stir the contents.
4. Place one straw each into slurry cups “2” and “3”. The two experimenters in each group should blow gently but steadily through each straw for 30 seconds.
5. Use the index cards to scrape any bubbles off the top of the slurry in each cup and place them on separate paper towels to dry. Label the deposited bubbles as “Trial 1”.
6. The recorder of each group should record the group’s observations for “Trial 1” on the data sheet while the experimenters should proceed immediately to Step 7. Don’t allow the cups to “rest” between trials.
7. The experimenters should begin “Trial 2” by repeating steps 4 to 6. Then repeat again for “Trial 3” and “Trial 4”. After each trial, the recorder should record the group’s observations on the data sheet.
8. Dispose of the slurries by placing them in a garbage receptacle lined with a strong plastic bag. Do not pour slurry into a drain.

9. Answer the questions in the “Flotation Process” section of the data sheet.

Activity II (Length: 30 minutes)

The objective of this activity is to research the remaining steps in the processing of copper ore. Students can work in pairs or alone.

1. Using resource books or internet access (as well as information from the *Ground Rules* film, Chapter 2), determine the remaining steps in the processing of copper ore. Answer the following questions:

    a. How pure is the copper after the flotation process (% of copper)?
    b. What is the next step in the processing of copper ore? Briefly describe this process. How pure is the copper after this step?
    c. What is the final step in the processing of copper ore to achieve pure copper? Briefly describe this process.
    d. How is copper typically packaged for distribution?
    e. What are some of the common uses of copper?

Discussion (Length: 30 minutes)

<u>Activity I:</u>
Review the observations made by each of the groups and the answers to the questions on the data sheet.

What happens to the remaining rock fragments left behind at the bottom of the flotation tank? This mixture, known as tailings, is typically pumped to a tailings impoundment where the water is removed and recycled back into the flotation process. The remaining waste rock must be stockpiled and eventually incorporated into the reclaimed landscape after mining operations have ceased.

Review the process of froth flotation in more detail. Why are the copper particles collected on the bubbles? Why does the addition of soap help separate the copper particles? What is the purpose of the air? Review the terms hydrophobic and hydrophilic. The soap is a surfactant which has a hydrophobic end and a hydrophilic end. In actual copper flotation processes, a specific surfactant is added that binds to the copper making it hydrophobic. The remainder of the solution remains hydrophilic. The hydrophobic mineral particles then attach to the air bubbles and float to the surface.

Activity II:
Briefly discuss the next steps involved in processing copper. After flotation, the copper concentrate contains only 20 to 40% pure copper. The next step in the process is to convert the copper concentration to 99% pure copper. This is accomplished in the smelting process where high temperatures are used to roast the concentrate, smelt it in a furnace and oxidize and reduce the molten material to progressively remove the unwanted elements, such as sulfur, iron, silicon and oxygen. Relatively pure copper (99%) is left behind. The final step in the process is called electro-refining or electro-winning. In this process, copper is purified through electrolysis. An electric current is passed through the material which separates the copper ions from the impurities. As the film shows, the copper is prepared in square sheets and bundled for distribution. The most common uses of copper are in electrical wiring, currency and piping.

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.

Extracting Copper from Sulfide Ore Data Sheet

Crushing Process:

Was it easy or difficult to crush the sulfide ore into small pieces?

Milling Process:

Trial	Changes in Sulfide Ore	Changes in Steel Shot	Changes in Water
1			
2			
3			

What does the jar represent?

What is the purpose of the steel shot?

What is the purpose of the screen?

Why is the milling process necessary?

Flotation Process:

Record the behavior of each slurry cup after each trial in the following table:

Trial	Slurry Cup 1 (slurry only; control)	Slurry Cup 2 (slurry with bubble liquid and air)	Slurry Cup 3 (slurry with air)
1			
2			
3			
4			

What was observed collecting onto the bubbles?

What was the purpose of injecting air into the slurry cups? What happened to the ore in the cups when air was added? Why?

Was there a difference in what was collected on the bubbles from Slurry Cups 2 and 3?

Was all of the copper in the slurry collected after 4 trials? Is this “pure” copper?

LEACHING TO SEPARATE METALS FROM ORE

Description

Students will conduct a leaching experiment to extract copper from copper ore. They will also experiment with materials containing iron and zinc and with other solvents.

VOCABULARY:

1. Ore
2. Ion
3. Leaching
4. Solution
5. Solvent
6. Hydrometallurgy
7. Acid
8. Precipitation

MATERIALS:

- *Ground Rules* film
- Finely crushed copper ore
- 100 mL Pyrex beaker or cup
- Plastic spoon
- ½ cup white vinegar
- Hot plate
- Saucepan
- Aluminum wire or aluminum foil
- Steel nail
- Zinc coated nail
- Copper wire
- Weak sulfuric acid solution
- Safety goggles

Introduction (Length: 20 minutes)

Watch Chapter 2 "Modern Mining" of the *Ground Rules* film. This chapter shows how copper is mined and processed at a large mine site in Chile.

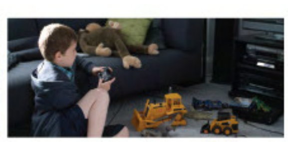
Ask students what leaching is and how it might be used in to process ore.

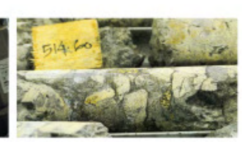
Leaching is one method that can be used to separate some metals from the ore in which they are found. The extraction of metals by use of chemical solutions is called hydrometallurgy. Leaching is one common example of hydrometallurgy.

Leaching is used in approximately 15% of world-wide copper production. Most of these operations are in Chile, Arizona and Australia.

Leaching utilizes a chemical solvent to dissolve or separate (leach) the metal from the ore, forming a solution from which the metal can be collected. The ore is piled onto a surface known as the "leaching pad" and it is then sprayed with the chemical and allowed to dissolve and drain. The concentrate solution can then be processed to recover the desired metal. Sulfuric acid for example, is often used to leach uranium, copper, and zinc ore. An aqueous solution of sodium or potassium cyanide is used to leach some gold and silver ores.





Activity I (Length: 20 minutes, plus follow-up)

The objective of this activity is to dissolve copper ions and extract them from the solution onto an aluminum wire.

Teacher Preparation:
1. Heat the vinegar in a sauce pan on the hot plate until it is boiling. This should be done in a fume hood prior to the activity.

Activity:
1. Put on safety goggles to avoid splashing vinegar solution into eyes. Preferably complete this activity in a fume hood.
2. Pour approximately 50 mL of hot vinegar into the Pyrex beaker or cup. This is the leaching solution. Note the color of the solution.
3. Add a tablespoon of the crushed copper ore to the Pyrex container (enough to cover the bottom).
4. Note the color of the leaching solution after the addition of the ore. What is happening?
5. Add a piece of aluminum wire or foil (3-4 inches long) with part of the wire in the solution and part hanging over the edge of the beaker.
6. Add a piece of copper wire as a control to demonstrate what happens to copper-containing materials in the reaction.
7. After a few minutes, remove the aluminum from the solution. Did the portion that was in the solution start to change color? If so, why?
8. Replace the aluminum in the solution and check after 30 minutes. Has a color change occurred? What is happening?
9. Leave the materials in the solution for a few days and make daily observations.

Activity II (Length: 20 minutes, plus follow-up)

The objectives of this activity are to observe what happens to the copper ore in a sulfuric acid solution and what happens to materials containing iron and zinc when placed in a leaching solution.

Activity:
1. Put on safety goggles to avoid splashing acid solutions into eyes. Preferably complete this activity in a fume hood.
2. Repeat Activity I using a weak sulfuric acid solution as the leaching solvent. How do the results compare to Activity I?
3. Prepare another two beakers with 50 mL of hot vinegar or the sulfuric acid solution.
4. Add a steel nail to one beaker and a zinc coated nail to the other. What happens?
5. Leave the materials in the solution for a few days and make daily observations.

Discussion (Length: 30 minutes)

Activity I:
Ask the students to explain what is happening in the beaker. What is vinegar composed of? Vinegar is a weak solution of acetic acid in water. What does the vinegar do to the copper ore? What form is the copper in when it is in solution? Discuss the term “ion”.

What color is the solution? Copper acetate ions have a blue-green color. How does the solution change over time?

Why was the aluminum wire added to the beaker? Did the aluminum wire change color? Why? Some of the copper ions in the solution precipitated onto the aluminum wire.

Why didn’t the aluminum leach from the wire? When aluminum is exposed to oxygen, it forms a thin layer of aluminum oxide on its surface which is relatively resistant to the corrosive effects of acetic acid.

Activity II:
What happened to the steel nail (containing iron) and the zinc coated nail? Iron and zinc are easily corroded by acetic or sulfuric acid. Leaching can also be used to extract iron and zinc from ore.

What happened to the copper ore in the sulfuric acid solution? How did the results compare to the vinegar solution? Which solution was more effective in leaching the copper ore?

MAKING STEEL AND STEEL ALLOYS

Description

Students will explore the process of steel production from iron ore. They will learn about metal alloys and how metal alloys are used to make stainless steel. They will also learn how steel can be recycled.

VOCABULARY:

1. Iron ore
2. Nickel
3. Chromium
4. Titanium
5. Silicon
6. Alloy
7. Corrosion resistance
8. Ingot
9. Ductile
10. Pig iron
11. Blast furnace

MATERIALS:

- Resource books or internet access
- Variety of objects made of steel

Introduction (Length: 15 minutes)

Ask the students if they know what an alloy is and to give an example of an alloy. An alloy is a mixture of two or more metals or elements. Some examples include brass, which is an alloy of copper and zinc, and bronze, which is an alloy of copper and tin.

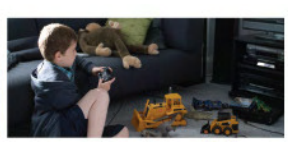
Steel is also an alloy. What is the most common metal used in steel? Iron.

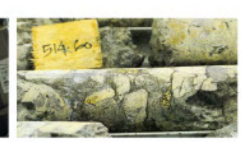
Pass around some objects made of different types of steel. Ask the students what is different about the types of steel used to make those objects.

Explain that the basic steel alloy includes iron and carbon. Steels are classified according to the amount of carbon they contain. The more carbon the steel has, the harder and more durable the steel is. Mild steels (the least durable steels) contain up to 0.25% carbon. Medium steels contain 0.25 to 0.45% carbon and high carbon steels contain up to 1.5% carbon.

A variety of other metals can be added to the basic steel alloy to make specific kinds of steel. Ask the students if they know what metals are added to make stainless steel (nickel and chromium).





Activity (Length: 45 minutes)

The objectives of this activity are to learn how iron ore is processed into steel, to learn about various steel alloys, and to learn how steel can be recycled.

1. Using resource books or internet access, research how iron ore is processed into steel. Answer the following questions:

    a. What is the name given to impure iron ore that is used in the steel-making industry?
    b. What is an ingot?
    c. How are the iron ore ingots melted?
    d. What type of furnace is used to melt the iron ore?
    e. How are the impurities removed from the iron ore?
    f. Name three elements that can be added to steel and what properties these metals provide to the steel.
    g. Name five uses of steel. What type of steel is used for each?
    h. How is steel made into sheets?
    i. How can scrap metals be used in the production of steel?
    j. How can steel be recycled into new steel?
    k. What percentage of steel is made from recycled metal in your country?
    l. Could steel be considered to be a renewable resource? Explain why or why not.

Discussion (Length: 30 minutes)

Discuss the process of making steel from iron ore. Explain that pig iron, an impure form of iron ore, is used to make steel. An ingot is a metal that is cast into a specific shape suitable for further processing. Iron ingots are melted in a blast furnace. Scrap or recycled iron can be added at this step and melted with the pig iron.

Limestone chunks are added to the blast furnace to remove impurities. The acidic impurities bind to the limestone and float to the top of the blast furnace. They are then skimmed off the top of the molten iron. Oxygen is blow into furnace to aid in removing the impurities.

Nickel and chromium can be added to create stainless steel. Most stainless steels contain approximately 18% chromium and 8% nickel. Nickel increases the ductile nature of the steel, while chromium provides corrosion resistance.

Titanium can also be added to steel to increase the strength of the steel. This type of steel is used for making airplanes and spacecraft. Silicon may be added to steel to make it softer and more pliable and to increase resistivity and permeability. Silicon steels are used in transformers, generators, motors, etc.

Recycling is an integral component of the steel making industry. Scrap iron can be added to the blast furnace and melted in the same manner as pig iron. In addition, steel can be recycled into new steel simply by melting it and reforming it into steel sheets. Steel is one of the most recycled materials in the world. The recycling rate of steel is typically quite high (>50% in most industrialized countries).

Discuss the students ideas on whether steel is a renewable resource. What is a renewable resource? A renewable resource is one that can be replenished at a rate comparable to or faster than its rate of consumption. Is this true for steel? Some people think that since steel can be recycled into new steel indefinitely, it could be considered to be a renewable resource. However, if our consumption of steel exceeds the rate at which it is recycled, then the steel making process continues to use raw materials harvested from the earth, which are not renewable.

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.

ORE PROCESSING | AGE:15 TO 18 | LENGTH: 2 HR | CURRICULUM: earth science, tools, machines

MINING EQUIPMENT

Description

Students will explore the types of equipment used on mine sites to load and haul ore to processing facilities, including trucks, loaders, drag-lines and remote-controlled vehicles.

VOCABULARY:

1. Loader
2. Excavator
3. Drag-line
4. Haul truck
5. Bucket wheel
6. Remote-controlled vehicles
7. Safety

MATERIALS:

- *Ground Rules* film
- Resource books or internet access

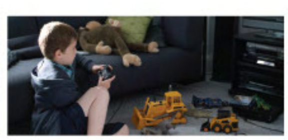
Introduction (Length: 30 minutes)

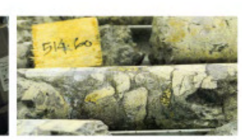
Watch Chapter 2 “Modern Mining”, Chapter 5 “Going Underground” and Chapter 8 “Reclamation” of the *Ground Rules* film. Chapter 2 shows haul trucks and draglines that are used to load and haul copper ore at an open pit mine in Chile. Chapter 5 shows some of the equipment that is used at an underground mine in Canada. Some of this equipment is remote-controlled to ensure worker safety (remote-controlled loaders). Chapter 8 shows a dragline in use at the Black Thunder mine in the United States. The dragline is used to scoop the coal out of the mine and stockpile it for hauling.

Discuss the importance of heavy equipment to the mining industry. Safety is one of the major considerations in the design of modern mining equipment. As shown in the film, equipment operators receive health and safety training and must follow strict health and safety protocols while operating heavy equipment on a mine site. The equipment must be continually inspected to ensure that is it working properly and safely.

Review the concepts of simple and complex machines and mechanical advantage. Explain that we can measure the effectiveness of a machine by calculating the mechanical advantage. The mechanical advantage can be used to determine how much easier a job has become with the help of the machine. The mechanical advantage equals the number of times a machine multiplies your effort (or force).





To calculate the mechanical advantage, divide the load by the force, as follows:

$$\text{Mechanical Advantage} = \frac{\text{Load}}{\text{Force}}$$

Give an example on the board: If a rock weights 100 lbs (load) and we create a simple machine that requires us to use 50 lbs of our force to lift the rock, then the mechanical advantage of our machine would be 2 (i.e., 100 / 50 = 2). In other words, the simple machine multiplied our effort by 2. It allowed us to do the work using half the effort it would have taken us to do the work without the machine.

As the mechanical advantage increases, the machine becomes more efficient and less effort is expended by the miner. This allows more work to be done. Engineers can use the mechanical advantage formula to make modifications to existing machines to further enhance efficiency.

Activity (Length: 60 minutes)

The objective of this activity is to learn about the equipment used to load and haul ore at mine sites. This activity can be done individually or in groups.

1. Each student or group of students should select a type of mining equipment used to load or haul ore. If possible, they should each select a different type of mining equipment.

2. Prepare a research report on this piece of equipment by answering the following questions:

    a. What is the purpose of this piece of equipment? What activities does it perform at a mine site?
    b. What type of mine would use this piece of equipment? (open pit, underground)
    c. What are the potential safety issues associated with using this piece of equipment at a mine site? What aspects of this piece of equipment enhance the safety of its operation?
    d. How big is this piece of equipment? How heavy a load can it lift or haul?
    e. Briefly describe how the equipment operates.
    f. What types of simple machines are used in this complex machine?
    g. How does this piece of equipment increase mechanical advantage?

Discussion (Length: 30 minutes)

Have the students present their findings to the class. Discuss the importance of these pieces of equipment to the functioning of mine sites. What are the safety issues associated with use of this equipment? What measures can be used to enhance the safe operation of mining equipment?

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

MINERALS AND REAL LIFE

Minerals and Everyday Life

AGES 11-13

GROUNDRULES

MINERALS AND EVERYDAY LIFE	AGE: 11 TO 13	LENGTH: 1 HR	CURRICULUM: mineral, nutrition/health, magnetism

MAGNETIC CEREAL

Description

Students will learn that some minerals are essential nutrients for human health. They will identify essential macro-minerals and micro-minerals and confirm the presence of iron in breakfast cereal.

VOCABULARY:

1. Essential minerals
2. Macro-minerals
3. Micro-minerals
4. Magnetism
5. Friction
6. Crushing process
7. Iron

MATERIALS:

- *Ground Rules* film
- Flaked cereal that is fortified with iron (Total works well)
- Nutrition labels and ingredient lists from a variety of breakfast cereals
- A strong magnet
- Small zip-lock bags
- Plates or shallow bowls
- Water
- Clear plastic cups
- Plastic straws or stir sticks
- Hand lenses or magnifying glasses

Introduction (Length: 15 minutes)

Watch Chapter 3 “Mining and the Modern World” of the *Ground Rules* film. Discuss the importance of minerals in our daily lives. Minerals have specific properties that make them useful to humans. All minerals come from the Earth’s crust and must be mined.

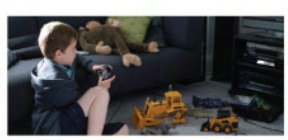
Ask the class whether they have ever eaten a mineral? What minerals can we eat? Why do we eat minerals?

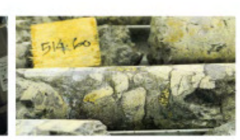
Have the students bring in nutrition labels and ingredient lists from several different brands of cereal. Identify the minerals.

Minerals only represent about 0.3% of our total intake of nutrients, but they are very important. Without these mineral nutrients, we wouldn’t be able to utilize the other 99.7% of the food we consume.

Macrominerals are minerals that we require in substantial amounts for proper nutrition. These include calcium, chloride, magnesium, phosphorus, potassium, sodium, sulfur and zinc. Microminerals are minerals that we require only in trace amounts. These include chromium, cobalt, copper, fluorine, iodine, iron, manganese, molybdenum, selenium, silicon and zinc. These minerals can be found in various foods and in supplements.





Activity (Length: 30 minutes)

The objective of this activity is to determine whether there is actually iron in breakfast cereal.

<u>Activity</u>:

1. Use a magnifying glass to examine a single flake of cereal closely. Can you see any visible traces of iron? No.
2. Place a few flakes of cereal on the table. Bring your magnet near the flakes and see if they are attracted or repelled by the magnet. You likely will not get a reaction.
3. Fill a plate or shallow bowl with water and float a few flakes of cereal on the surface. Hold the magnet close to the flakes and watch closely for any movement. Any movement that occurs will be slight, so they will need to be patient. With practice, you should be able to make the flakes rotate or move them around the bowl in a pattern.
4. Fill a zip-lock bag half full with cereal. Seal the bag and crush the cereal into a fine powder.
5. Pour enough water into the bag to make a thin cereal paste. It should be about the consistency of thick soup.
6. Pour your cereal mixture into a clear plastic cup.
7. Hold the magnet against the outside of the cup in one location. Stir the mixture gently with a straw or stir-stick (nothing magnetic). After two or three minutes, you should see an accumulation of iron particles on the side of the cup near your magnet. Use a magnifying glass to see the particles better.

Discussion (Length: 15 minutes)

Why did we use a magnet to test for the presence of iron? Were you able to see the iron in the cereal flake? Why not?

Why was it easier to move the flakes around when they were floating on the water than when they were on the table? Friction between the flakes and the table surface was too great to be overcome by the attraction of the iron to the magnet. By floating the flakes on the surface of water, friction was reduced.

What step in the mining process was simulated by crushing the cereal into a powder? This process simulates the crushing process used in mining to extract minerals (such as iron) from the surrounding waste rock.

What is the function of iron in the human body? Iron carries oxygen to the cells and is necessary for the production of energy, the synthesis of collagen, and the functioning of the immune system. Iron is found in meat, fish, beans, spinach, molasses, brewer's yeast, broccoli and seeds. It can also be added to various foods, such as cereal.

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.

MAKING A FLASHLIGHT

Description

Students will identify some of the properties of copper, two of its common alloys, and several of its main uses. They will explore the electrical and malleable properties of copper by building a flashlight using copper wire and by creating an art sculpture.

VOCABULARY:

1. Copper
2. Electricity
3. Circuit
4. Tarnish
5. Bronze
6. Brass
7. Conductor
8. Malleable

MATERIALS:

- *Ground Rules* film
- D cell batteries
- Copper wire
- Small light bulbs
- Examples of objects made of copper (optional)
- Cards with names of common objects written on them

Introduction (Length: 15 minutes)

Watch Chapter 2 “Modern Mining” and Chapter 3 “Mining and the Modern World” of *Ground Rules* film. Chapter 2 explores the process of copper mining at a modern mine in Chile. Chapter 3 shows how minerals, including copper, are used to make a variety of products we use in our everyday lives.

After watching the film, make a list of everyday items that use copper. Discuss some of the major uses of copper and some of its important properties. Pass around some objects that are made of copper (optional).

Copper conducts heat and electricity better than any other metal, except silver. Copper is used in wires to conduct electricity. Copper is also used in cookware to conduct and retain heat. It is also used in a variety of electronics products.

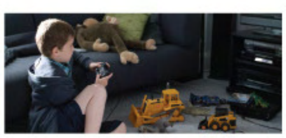
Copper is also malleable and does not corrode easily. This makes it an ideal element for making pipes for plumbing, parts for automobiles and airplanes, tools, and pieces of art.

When copper tarnishes, it turns green on the surface. Ask if anyone has seen green roofs on old buildings. When you see a green roof, you know it is made of copper. Some of the biggest deposits of copper in the United States were found by accident when prospectors noticed greenish rock sticking out of the ground.

Two common alloys of copper are bronze (a mixture of tin and copper) and brass (a mixture of zinc and copper). Brass and bronze are stronger than pure copper and do not corrode in air or water except for a small amount of tarnishing.

Copper can be recycled and reused. Approximately one-third of the copper used today is recycled. The rest comes from recently mined copper ore.



Copper is mined in many countries around the world. The biggest producer of copper is Chile, followed closely by the United States. Canada, Russia, Indonesia, Australia, Peru, China and Zambia are also large copper producers. In the United States, most of the copper mining is conducted in Arizona, Utah, New Mexico, Nevada and Montana. In Canada, copper is mined in British Columbia, Ontario, New Brunswick and the Northwest Territories.

Activity I (Length: 15 minutes)

The objective of this activity is to build a flashlight using copper wire.

1. Give every student a D cell battery, two small pieces of copper wire and a small light bulb.
2. Connect one piece of the wire to the light bulb at one end and the positive end of the battery at the other.
3. Connect the second wire to the light bulb and touch it to the negative end of the battery. What happens?

Activity II (Length: 15 minutes)

The objective of this activity is to discover the malleable property of copper.

1. Divide the class into groups of 3 or 4.
2. Give each group some copper wire and a card with the name of an object written on it.
3. Ask each group to use their copper wire to build the object that is written on their card.

Discussion (Length: 15 minutes)

<u>Activity I</u>:
What happens when the wires are connected to the battery? Discuss the flow of electricity through the wire and what happens when one wire is disconnected. Introduce the terms “circuit” and “electrical conductor”. Copper is an electrical conductor because it lets electricity travel through it.

<u>Activity II</u>:
Have each group try to guess what objects the sculptures represent. What property of copper makes it ideal for creating sculptures?

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

MINERALS AND EVERYDAY LIFE	AGE: 11 TO 13	LENGTH: 1.5 HR	CURRICULUM: minerals, composition of objects

MINERAL CONTENT MATCHING GAME

Description

Students will explore items within their classroom, school or schoolyard and determine which minerals were used to make them.

VOCABULARY:

1. Minerals
2. Properties

MATERIALS:

- *Ground Rules* film
- Sets of “mineral content” cards
- Masking tape
- Timer
- Resource books or information sheets (optional)

Introduction (Length: 10 minutes)

Watch Chapter 3 “Mining and the Modern World” of the *Ground Rules* film. Discuss the importance of minerals in our daily lives. Minerals have specific properties that make them useful to humans. All minerals come from the Earth’s crust and must be mined.

Explain that a variety of minerals have been used to make common items in their classroom, school and schoolyard. Select an example of a classroom object that will not be used in the activity. Ask the students what minerals are used to make that object. Why were those minerals selected? What properties of those minerals made them useful for the purpose of creating that item?

Activity (Length: 50 minutes)

The objective of this activity is to determine the mineral content of common items around the classroom, school or schoolyard.

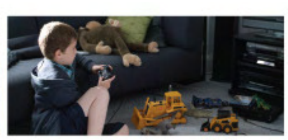
Preparation:

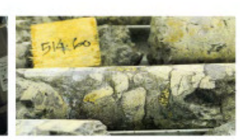
1. Create 10 stations inside the classroom, school and/or schoolyard that highlight different items, such as foundation/sidewalk, bricks, nails, wall board, paint, windows, door knobs, floor tiles, plumbing, wiring, toilets/sinks, desks, chairs, playground equipment, television, computers, pencils, blackboards, etc.
2. Prepare sets of 10 “mineral content” cards that list the key minerals used in each item (1 set per group). Each set should be a different color.
3. Optional: put out some resource books or information sheets at the front of the class.

Activity:

1. Divide the class into groups of 3 or 4 students.
2. Give each group a set of colored mineral content cards and a roll of masking tape.





3. Set the timer for 30 minutes.
4. Each group must visit each station and attach the correct mineral content card to the station with masking tape (face down, so the other groups can't see the answer).
5. Each group must successfully match their mineral content cards with the correct stations. They can revisit stations and change their cards as often as they want within the allotted time. Optional: they can consult the resource materials at the front of the class for assistance.
6. Have all groups return to their desks when the timer goes off.

Discussion (Length: 30 minutes)

Which group correctly matched the most mineral content cards? Which items were the most difficult to determine? Which were the easiest? Can you find one object in the classroom that does not include items that are mined? Discuss the importance of mines to our everyday lives.

Pick one or two of the items evaluated in this exercise and discuss the properties of the minerals used to make those items. Why were those minerals chosen to make the item? For example, why is copper used in electrical wires?

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.

Mineral content of some common items at school:

Windows: sand, silica and feldspar
Nails and screws: iron and steel
Bricks: clay
Wallboard: gypsum
Doorknobs, locks and hinges: steel, brass, copper, zinc, and iron
Blackboards: slate particles
Paint: zinc
Galvanized Gutters/Eavestroughs: iron and zinc
Concrete foundation: clay, shale, gypsum, and limestone
Insulation: vermiculite, silica and feldspar
Toilets: porcelain, clay, and feldspar
Sewer pipes: clay and iron
Plumbing: copper and zinc or stainless steel (made of: iron, nickel and chromite)
Playground equipment: steel (made of: iron, nickel and chromite)
Wiring: copper or aluminum
Pencil: graphite, aluminum or brass for the metal ring that holds the eraser

AGE: 11 TO 13 | LENGTH: 1.5 HR | CURRICULUM: minerals, experiment, health

TOOTHPASTE EXPERIMENT

Description

Students will learn that a variety of minerals are used to make toothpaste. They will discover how the mineral fluorite in toothpaste helps protect against tooth decay.

VOCABULARY:

1. Acid
2. Plaque bacteria
3. Tooth decay
4. Fluorspar (fluoride)
5. Mica
6. Sodium carbonate
7. Zinc

MATERIALS:

- *Ground Rules* film
- Toothpaste containing sodium fluoride
- Glass measuring cups
- Fresh eggs
- Vinegar
- Spoons
- Plastic wrap
- Marker
- Clear nail polish
- Reusable cloth
- Several tubes of different brands of toothpaste

Introduction (Length: 30 minutes)

Ask the class if they can name a mineral used in toothpaste. Pass around a few tubes of different brands of toothpaste and ask the class to look at the ingredient list. Ask the class to pick out some of the mineral ingredients. Make a list on the blackboard and see which ingredients are most common among the different brands.

Watch Chapter 3 “Mining and the Modern World” of the *Ground Rules* film. Pause the film at the scene where the mother is brushing her teeth. Note that toothpaste is composed of several minerals including calcium carbonate, limestone, sodium carbonate, fluorite, mica and zinc.

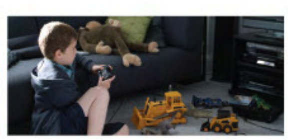
Discuss how there are many minerals found in toothpaste and that every brand of toothpaste contains a slightly different mixture of minerals. However, all toothpastes contain abrasive minerals to rub the plaque away. The most common abrasive minerals used in toothpaste include silica, limestone and calcium carbonate. Most toothpaste brands also contain the mineral fluorite, which is composed of calcium fluoride. This mineral makes the tooth more resistant to decay.

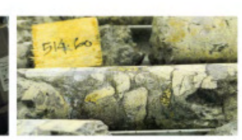
Sodium carbonate is used in some toothpastes whiten teeth.

Zinc is sometimes used in toothpastes as an anti-bacterial agent to prevent gingivitis (gum disease).

Toothpastes may also contain other minerals and ingredients to make the toothpaste sparkly (mica), to make it white (titanium), to make it thick (sand), to whiten teeth (sodium carbonate) and to fight bacteria (zinc).





Discuss some of the common minerals found in toothpaste, what types of rocks they are found in, and where they are mined. Here is some information on four common mineral ingredients:

1) Fluorite (also called fluorspar)
Fluorspar or fluorite are two names given to minerals composed of calcium fluoride (CaF_2). Fluoride makes the entire tooth structure more resistant to decay and promotes remineralization, which aids in repairing early decay before the damage can even be seen. Fluorspar/fluorite is found in a variety of geologic environments. It occurs in granite (igneous rock) and in large deposits in limestone (sedimentary rock). It can also be found in the cracks and holes in sandstone. Fluorspar is not mined in the United States. More than 15 countries produce fluorspar. China, Mexico, and South Africa are the largest producers. There is a fluorspar mine in Newfoundland, Canada. China supplies about two-thirds of the fluorspar used in the United States.

2) Mica
Mica is the mineral added to toothpaste that makes the substance sparkle. Large flakes and sheets of mica minerals are found in some metamorphic and igneous rocks. The commercially important micas are muscovite and phlogopite. India and Russia are the world's largest producers of sheet mica. A very small amount of mica is produced in the United States. The largest sheet of mica ever mined in the world came from a mine in Quebec, Canada. Sheet, scrap and flake mica are commercially important. Other primary uses for scrap and flake mica are in joint compound, paint, roofing, well drilling additives, and rubber products.

3) Sand (silica)
Sand is added to toothpaste to make the paste thicker. Most sand and gravel is composed of the mineral quartz, with varying amounts of feldspar, rock fragments, and other mineral materials. The commercial use of sand and gravel falls into two categories: construction sand and gravel, and industrial sand and gravel. Industrial sand and gravel, which is often termed "silica," "silica sand," or "quartz sand," includes sand and gravel with high quartz content. Such sand and gravel is used, for example, in glassmaking. Construction sand and gravel typically has a lower silicon dioxide content than does industrial sand and gravel. It is mixed with other materials, such as cement in concrete foundations, roads, and buildings, or is used as is in road bases. Construction sand and gravel is mined in all U.S. states and industrial sand and gravel is mined in 37 U.S. states. Canada is one of the leading nations processing and producing industrial sand and gravel. The Unites States imports a substantial amount of sand from Canada.

4) Sodium Carbonate
Sodium carbonate is commonly known as washing soda. It is used as a whitening agent in toothpaste, usually in combination with hydrogen peroxide. Sodium carbonate is soluble in water, but can occur naturally in arid regions, especially in the mineral deposits formed when seasonal lakes evaporate. Sodium carbonate is mined in several areas of the United States and Canada. The most important use for sodium carbonate is in the manufacture of glass. When heated to very high temperatures, combined with sand (silicon dioxide) and calcium carbonate, and cooled very rapidly, glass is produced.

Activity (Length: 45 minutes, over 7 days)

The objective of this activity is to demonstrate the ability of the mineral fluorite in toothpaste to protect teeth from decay. This experiment will be conducted in stages over 7 days. Eggs should be room temperature to begin this experiment.

Preparation (5 minutes):
1. Divide the class into groups of 2 or 3.
2. Explain that in this activity, the eggshell will represent a tooth. Eggshells are composed largely of calcium carbonate. Calcium is also a major component in the enamel of our teeth. Therefore, eggshells are a good surrogate to use in this experiment. Both eggshells and teeth can be weakened by acids.
3. Explain that they will be using vinegar in this activity. Vinegar is an acid that is similar to the acids made by plaque bacteria in our mouths. Acids can cause tooth decay and cavities.
4. Ask the students to hypothesize what they think will happen if the egg is immersed in vinegar.
5. Ask the students to hypothesize what they think will happen if the egg is treated with toothpaste and then immersed in vinegar.

Day 1 (15 minutes):
1. Give each group an egg, a measuring cup and a tube of toothpaste.
2. With clean hands, each group should wash their egg with water and dry with a cloth.
3. Groups should empty the entire contents of the toothpaste into the measuring cup and pat down with a spoon to level the toothpaste and remove any air bubbles.
4. Each group should mark one side of the egg with a felt-tipped marker and cover this mark with clear nail polish to protect it from the vinegar.
5. After the nail polish has dried, each group can place their egg into the measuring cup, mark side down. Push the egg gently into the toothpaste, so it covers approximately half of the egg. Make sure egg does not touch the bottom of the cup.
6. Cover the cup tightly with plastic wrap and leave in a safe place at room temperature for at least 4 days.

Day 5 (5 minutes):
1. On day 5, groups should rinse all the toothpaste off the egg with warm water and let the egg dry overnight.
2. Each group should also thoroughly clean their measuring cup.

Day 6 (10 minutes):
1. Each group should pour enough vinegar into a clean measuring cup to cover the egg.
2. They should then put the egg on a spoon and carefully lower the egg into the measuring cup, ensuring that it is fully immersed in vinegar. If not, additional vinegar can be added slowly to the measuring cup.
3. The spoon should be rested on top of the egg to keep it under the vinegar.
4. Cover the cup tightly with plastic wrap and record the time. The egg must be left in the vinegar for at least 7 hours and no more than 12 hours. If you are not going to be in the classroom after 7 hours, take the egg out of the vinegar and wash it in warm water before you leave. Write down how many hours it was in the vinegar. As soon as the students come in the next day, they should put the egg back into the vinegar and continue recording the time.

Day 7 (10 minutes):

1. After 7 hours in the vinegar, groups should remove the egg and gently tap the shell with their finger on the unmarked side. If it is still hard, they should return it to the vinegar and recheck it every hour until the shell begins to soften.
2. When the unmarked side is soft, remove the egg and gently wash it with warm tap water.
3. Check the hardness of the marked side of the eggshell. How does it compare to the unmarked side?

Discussion (Length: 15 minutes)

Discuss the purpose of fluoride in toothpaste. Were the students' hypotheses correct?

Compare the fluoride content of several different brands of toothpaste. Which brand of toothpaste do you think would be most protective of tooth decay? Why?

What are the disadvantages of including more fluoride in toothpaste? Discuss the condition called fluorosis in which excess fluoride ingestion can lead to discoloration of the teeth. This is why toothpaste should never be swallowed and why levels of fluoride in tap water are typically low.

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

MINERALS AND EVERYDAY LIFE | AGE: 11 TO 13 | LENGTH: 1.5HR | CURRICULUM: earth science, geography, mapping

WHICH MATERIALS IN A PENCIL ARE MINED/GROWN?

Description

Students will determine which raw materials used to make a pencil are mined and which are grown.

VOCABULARY:

1. Graphite
2. Latex
3. Soybean oil
4. Pumice
5. Sulfur
6. Calcium
7. Barium
8. Aluminum
9. Brass (copper, zinc)

MATERIALS:

- *Ground Rules* film
- Traditional wooden pencils with eraser ends
- Access to resource books or internet
- Map of the world, with labeled countries
- Map of home country, with labeled states, provinces or territories
- Multi-colored push-pins and bulletin board

Introduction (Length: 10 minutes)

Watch Chapter 3 “Mining and the Modern World” of the *Ground Rules* film. Discuss the importance of minerals in our daily lives. Minerals have specific properties that make them useful to humans. All minerals come from the Earth’s crust and must be mined.

Explain that a variety of minerals have been used to make common items in their classroom, school and schoolyard. Select a common class room object. Ask the students what minerals are used to make that object. Why were those minerals selected? What properties of those minerals made them useful for the purpose of creating that item?

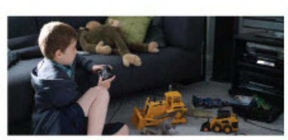
Ask the class if they know how many minerals are used to make a pencil? Explain that they will be participating in an activity to discover the natural resources used to make a pencil.

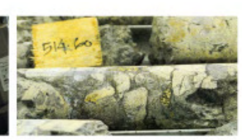
Activity I (Length: 40 minutes)

The objectives of this activity are to determine which raw materials are used to make pencils, whether they are mined or grown, and where the raw materials come from.

<u>Preparation</u>:
1. Make a list on the board, in random order, of all of the mined or grown resources that are used to make a pencil. These include: graphite, cedar wood, clays, soybean oil, latex, pumice, sulfur, calcium, barium, aluminum or brass (copper and zinc), hematite and limonite.
2. Assign a push-pin color to each resource.
3. Attach the maps to the bulletin board.





Activity:
1. Ask the class to identify the major parts of a pencil and make a list on the board beside the resource list. These include: the part that writes, the wood, the eraser, the metal band that holds the eraser, paint and glue.
2. One at a time, ask a student to come up to the board and draw a line to match a resource with the part of the pencil it is used to make. Continue until all of the resources have been used.
3. As a class identify which of these resources are mined and which are grown.
4. Divide the class into groups. Each group will research one of the resources used to make a pencil. Provide each group with some resource books, information sheets or access to the internet. Ask them to identify a country (either their home country, if applicable, or another country close to their home country) where the resource is mined or grown. If the resource if mined or grown in their home country, ask them to further identify which states, provinces or territories of the country mine or grow the resource.
5. Have each group come up to the bulletin board and place their colored push-pins on the states, provinces or territories within their home country and/or neighbouring countries where the resource is mined or grown.

Activity II (Length: 20 minutes)

1. Using the internet or resource books, each group should research one of the mined resources used to make a pencil in more detail (each group should do a different resource).
2. Determine how the resource is mined in their home country.
3. Identify other uses of this resource.

Discussion (Length: 20 minutes)

Activity I:
Ask the students what they learned in this activity. Review the results plotted on the maps. How many countries does it take to make a pencil? Does any country have all of the natural resources necessary to make a pencil? Ask them to extrapolate what they have learned about pencils, a relatively simple object, to more complex objects like televisions or computers.

Activity II:
Have the groups come to the front of the class and share what they have learned about each of the mined resources used to make a pencil.

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.

Answers (note that this list is not exhaustive)

Cedar wood (or basswood): used to make the wood part of the pencil; cedarwood from California and Oregon (US), Australia; basswood from China
Graphite: for the writing core; from Montana, Mexico, Australia, Ceylon
Clay: used to reinforce the writing core; from Kentucky and Georgia (US), Australia
Soybean oil: used to make eraser; from Brazil, Argentina, China, India
Latex: from trees; used to make eraser; from Latin America, Thailand, Malaysia, Indonesia, India
Pumice: used to reinforce eraser; from California or New Mexico (US), New Zealand
Sulfur, calcium, barium: used to make eraser; throughout United States, Canada, Mexico, Australia
Aluminum or brass (copper and zinc): used to make metal band; mined in 13 US states, 9 Canadian provinces, Australia; copper mined in Chile, United States, Canada and Australia; zinc mined in Mexico, Canada, United States and Australia
Hematite and limonite: natural pigments used to make orange paint (also a variety of synthetic chemicals used in paint and lacquer)

Note that glue is also used to hold the pencil parts together. A variety of natural and synthetic compounds can be used to make glue.

GROUNDRULES

MINERALS AND REAL LIFE

Minerals and Everyday Life

AGES 13-15

GROUNDRULES

MINERALS AND EVERYDAY LIFE | AGE: 13 TO 15 | LENGTH: 1.5DAY | CURRICULUM: earth science, minerals

CONSUMPTION OF MINERAL RESOURCES

Description

Students will learn how dependent they are on mineral resources from mines by keeping a list of all the items they use during one school day and determining which minerals are used in these items.

VOCABULARY:

1. Minerals
2. Non-renewable resource
3. Consumption

MATERIAL:

- *Ground Rules* film
- Paper and pencils

Introduction (Length: 15 minutes)

Watch Chapter 3 “Mining and the Modern World” of the *Ground Rules* film. Discuss the importance of minerals in our daily lives. Minerals have specific properties that make them useful to humans. All minerals come from the Earth’s crust and must be mined.

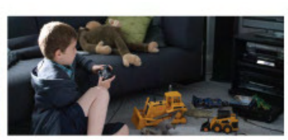
As shown in the film, a variety of minerals are used to make common items. Recall a few examples of items mentioned in the film. What minerals were used to make them? Ask the students how many minerals they think they might use in a typical school day.

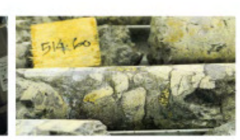
Activity (Length: 1 school day + 60 minutes)

The objective of this activity is to learn about consumption of mineral resources in our everyday lives.

1. Each student should make two hypotheses prior to this activity: how many minerals they think they use in a typical school day; and which minerals they think they use most often at school.
2. Over a full school day, each student should keep a list of all the items he/she uses. This should include items used in the classroom as well as items used during breaks and at lunch.
3. They should then identify some of the minerals used to make each of those items.
4. Each student should determine the number of different minerals he/she used in a school day and the five most common minerals used.





Discussion (Length: 45 minutes)

Create a summary table on the blackboard. Have the students help generate the column of items used in a school day by recalling some of the items on their list. As a class, identify the minerals used to make each of these items. Once a complete list has been generated, ask each student to come up and place a check mark beside all of the items they used in a school day. What were the most popular items used at school? Which minerals were used most often? How many different minerals were used by the class during a school day? How did the results compare to the student hypotheses? Did students overestimate or underestimate their consumptive habits? Extrapolate to how many different minerals they think they might use in a 24 hour period (at school and at home).

Discuss the implications of their findings. How dependent are we on mined minerals? Are these renewable or non-renewable resources? As long as we continue to use these items in our daily lives, we will be dependent on mining. How will we be able to sustain our consumptive habits in the future?

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

MINERALS AND EVERYDAY LIFE | AGE: 13 TO 15 | LENGTH: 1 HR | CURRICULUM: minerals, composition of objects

MINERALS AT SCHOOL

Description

Students will explore items within their classroom, school or schoolyard and determine which minerals were used to make them, where these minerals are mined, and how the properties of these minerals are useful.

VOCABULARY:

1. Minerals
2. Properties

MATERIALS:

- *Ground Rules* film
- Data sheet (provided)
- Resource books, information sheets or access to the internet

Introduction (Length: 10 minutes)

Watch Chapter 3 "Mining and the Modern World" of the *Ground Rules* film. Discuss the importance of minerals in our daily lives. Minerals have specific properties that make them useful to humans. All minerals come from the Earth's crust and must be mined.

Explain that a variety of minerals have been used to make common items in their classroom, school and schoolyard. Select an example of a classroom object that will not be used in the activity. Ask the students what minerals are used to make that object. Why were those minerals selected? What properties of those minerals made them useful for the purpose of creating that item?

Activity (Length: 40 minutes)

The objective of this activity is to determine the mineral content of common items around the classroom, school or schoolyard.

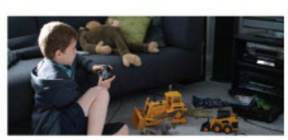
<u>Preparation</u>:

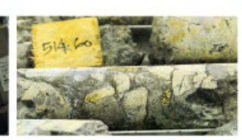
1. Create 10 stations inside the classroom, school and/or schoolyard that highlight different items, such as foundation/sidewalk, bricks, nails, wall board, paint, windows, door knobs, floor tiles, plumbing, wiring, toilets/sinks, desks, chairs, playground equipment, television, computers, pencils, blackboards, etc.

<u>Activity</u>:

1. Divide the class into groups of 2 students.
2. Each group must select 10 items within the classroom or schoolyard. Record the 10 items in the first column on the data sheet. In brackets, also record the parts of this item (for example, a door is composed of a door knob, hinges and the door itself).
3. Using resource books, information sheets or the internet, each group must identify the minerals that make up each item. For items that are composed of many minerals, they





should list no more than 5 minerals. Record the minerals in the second column on the data sheet.

4. Next, each group should determine where the minerals in each item are mined. Record up to 5 countries for each mineral in the third column on the datasheet.
5. Finally, for each item, identify the property(ies) of each mineral that make it useful to the item evaluated (e.g., copper is useful for wiring because it can conduct electricity). Record the properties in the fourth column on the datasheet.

Discussion (Length: 10 minutes)

Have each group present their findings to the class for 2 of the items on their list. Try not to duplicate items already reported by previous groups.

Did anyone pick an item that is composed of more than five minerals? Televisions or computers are two items in a classroom that are composed of many minerals.

Did anyone pick an item that is not composed of any minerals? One example may be a wooden table or desk. But even this type of item may have nails or staples that are composed of minerals. Finding an item that is not composed of minerals should be hard to do and will emphasize the importance of minerals in our everyday lives.

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.

Minerals at School Data Sheet

Item	Minerals	Mining Locations	Properties
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

MINERALS IN MY HOUSE

Description

Students will play a matching game to learn what minerals are used in common household items.

VOCABULARY:

1. Minerals
2. Properties
3. Lifecycle
4. Recycling

MATERIALS:

- *Ground Rules* film
- Sets of “mineral content” cards
- Masking tape

Introduction (Length: 15 minutes)

Watch Chapter 3 “Mining and the Modern World” of the *Ground Rules* film. Discuss the importance of minerals in our daily lives. Minerals have specific properties that make them useful to humans. All minerals come from the Earth’s crust and must be mined.

As shown in the film, a variety of minerals are used to make common household items. Recall a few examples of household items mentioned in the film that will not be used in the activity. Why were those minerals selected? What properties of those minerals made them useful for the purpose of creating that item?

Activity (Length: 30 minutes)

The objective of this activity is to determine the mineral content of common household items.

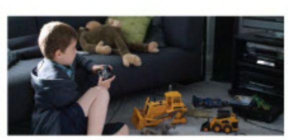
<u>Preparation</u>:

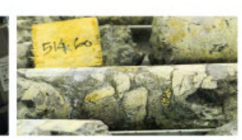
1. List 10 common household items on the board.
2. Prepare a set of cards containing the minerals used to make those 10 items. One mineral should be written on each card.

<u>Activity</u>:

1. Place all the mineral cards face down on a desk near the blackboard.
2. One at a time, have each student come up to the board, pick a card from the pile and attach it with masking tape beside the household item they think contains that mineral. Remind the class that several minerals may be used in one item.
3. Repeat #2 until all the mineral cards are used.
4. Go through each item and ask the class if the minerals placed beside it are correct. Invite students to come up to the board to correct any mistakes.
5. Continue #4 until the class thinks they have everything correct.
6. Review the correct answers with the class.





Discussion (Length: 15 minutes)

Pick one or two of the items for further discussion. For each item, ask the class why they think those specific minerals were used to make the item. What are the properties of those minerals that make them useful to the household item? Discuss the lifecycle of the minerals used in those items. Where in the world are those items mined? Ask the class if the item can be disposed in a regular landfill after its useful life. Can some of the minerals be separated from the item and recycled?

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.

Household Items and Minerals (from Chapter 3 of Ground Rules)

Wallboard – gypsum, clay, perlite, vermiculite, aluminum hydrate, borates
Paint – titanium dioxide, kaolin, calcium carbonate, mica, silica, wollastonite
Glass – silica, quartz, lead, titanium, sodium carbonate
Door Knob – nickel
Speakers – aluminum, cobalt, silver, silica, iron, titanium, graphite, mica, carbon, strontium, neodymium
Plastic – calcium carbonate, talc, wollastonite, barium sulfate, clay, mica
Keys – nickel
Stainless steel – iron, nickel, molybdenum, chrom
Non-stick coating – fluorite
Ceramic tiles – clay, feldspar, fluorite, lithium, silica, talc
Countertop – titanium dioxide, calcium carbonate, aluminum hydrate
Knife – chromium
Table salt – halite, iodine
Sugar – limestone, lime
Toothpaste – calcium carbonate, limestone, sodium carbonate, fluorite, mica, zinc
Cosmetics – calcite, hematite, kaolinite, mica, silica, talc, titanium, zinc
Carpet – calcium carbonate, limestone
Textiles – antimony, feldspar, tungsten
Dish soap – halite, sodium carbonate
Can opener – iron, nickel, chromium, molybdenum
Incandescent light bulbs – tungsten
Window panes – silica, lime, sodium carbonate, calcium carbonate, halite, feldspar
Brick – kaolin, shale, barium, manganese
Jewelry – gold, silver, platinum, diamonds
Soda cans – aluminum

Others

Baby powder – talc
Cement - limestone
Insulation - vermiculite
Matches – sulfur
Sun block – zinc
Thermometer – mercury
Utensils – nickel, iron, silver

GROUNDRULES

MINERALS AND EVERYDAY LIFE | AGE: 13 TO 15 | LENGTH:1 HR | CURRICULUM: earth science, health

MINERALS IN TOOTHPASTE

Description

Students will learn about the uses of various minerals in toothpaste through experimentation.

VOCABULARY:

1. Acid
2. Plaque bacteria
3. Tooth decay
4. Fluorspar (fluoride)
5. Mica
6. Sodium carbonate
7. Zinc

MATERIALS:

- *Ground Rules* film
- 3 different brands of toothpaste containing different ingredients
- Toothbrushes (1 per group)
- Small ceramic tiles, beige colored (3 per group)
- Container of water
- Safety goggles
- Felt-tipped black marker
- Small white porcelain squares (available at most hardware stores)

Introduction (Length: 20 minutes)

Ask the class if they can name a mineral used in toothpaste. Pass around a few tubes of different brands of toothpaste and ask the class to look at active ingredient list. Make a list on the blackboard and see which ingredients are most common among the different brands.

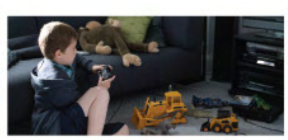
Watch Chapter 3 “Mining and the Modern World” of the *Ground Rules* film. Pause the film at the scene where the mother is brushing her teeth. Note that toothpaste is composed of several minerals including calcium carbonate, limestone, sodium carbonate, fluorite, mica and zinc.

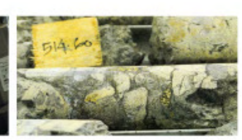
Discuss how there are many minerals found in toothpaste and that every brand of toothpaste contains a slightly different mixture of minerals. However, all toothpastes contain abrasive minerals to rub the plaque away. The most common abrasive minerals used in toothpaste include silica, limestone and calcium carbonate. Most toothpaste brands also contain the mineral fluorite, which is composed of calcium fluoride. This mineral makes the tooth more resistant to decay.

Sodium carbonate is used in some toothpastes whiten teeth.

Zinc is sometimes used in toothpastes as an anti-bacterial agent to prevent gingivitis (gum disease).





Toothpastes may also contain other minerals and ingredients to make the toothpaste sparkly (mica), to make it white (titanium), to make it thick (sand), to whiten teeth (sodium carbonate) and to fight bacteria (zinc).

Discuss some of the common minerals found in toothpaste, what types of rocks they are found in, and where they are mined. Here is some information on four common mineral ingredients:

1) <u>Fluorite (also called fluorspar)</u>
Fluorspar or fluorite are two names given to minerals composed of calcium fluoride (CaF_2). Fluoride makes the entire tooth structure more resistant to decay and promotes remineralization, which aids in repairing early decay before the damage can even be seen. Fluorspar/fluorite is found in a variety of geologic environments. It occurs in granite (igneous rock) and in large deposits in limestone (sedimentary rock). It can also be found in the cracks and holes in sandstone. Fluorspar is not mined in the United States. More than 15 countries produce fluorspar. China, Mexico, and South Africa are the largest producers. There is a fluorspar mine in Newfoundland, Canada. China supplies about two-thirds of the fluorspar used in the United States.

2) <u>Mica</u>
Mica is the mineral added to toothpaste that makes the substance sparkle. Large flakes and sheets of mica minerals are found in some metamorphic and igneous rocks. The commercially important micas are muscovite and phlogopite. India and Russia are the world's largest producers of sheet mica. A very small amount of mica is produced in the United States. The largest sheet of mica ever mined in the world came from a mine in Quebec, Canada. Sheet, scrap and flake mica are commercially important. Other primary uses for scrap and flake mica are in joint compound, paint, roofing, well drilling additives, and rubber products.

3) <u>Sand (silica)</u>
Sand is added to toothpaste to make the paste thicker. Most sand and gravel is composed of the mineral quartz, with varying amounts of feldspar, rock fragments, and other mineral materials. The commercial use of sand and gravel falls into two categories: construction sand and gravel, and industrial sand and gravel. Industrial sand and gravel, which is often termed "silica," "silica sand," or "quartz sand," includes sand and gravel with high quartz content. Such sand and gravel is used, for example, in glassmaking. Construction sand and gravel typically has a lower silicon dioxide content than does industrial sand and gravel. It is mixed with other materials, such as cement in concrete foundations, roads, and buildings, or is used as is in road bases. Construction sand and gravel is mined in all U.S. states and industrial sand and gravel is mined in 37 U.S. states. Canada is one of the leading nations processing and producing industrial sand and gravel. The Unites States imports a substantial amount of sand from Canada.

4) <u>Sodium Carbonate</u>
Sodium carbonate is commonly known as washing soda. It is used as a whitening agent in toothpaste, usually in combination with hydrogen peroxide. Sodium carbonate is soluble in water, but can occur naturally in arid regions, especially in the mineral deposits formed when seasonal lakes evaporate. Sodium carbonate is mined in several areas of the United States and Canada. The most important use for sodium carbonate is in the manufacture of glass. When heated to very high temperatures, combined with sand (silicon dioxide) and calcium carbonate, and cooled very rapidly, glass is produced.

Activity (Length: 30 minutes)

The objective of this activity is to determine which brands of toothpaste, and which minerals, are most effective in removing a stain from ceramic tiles and porcelain.

Preparation:
1. Divide the class into groups of 2 or 3.
2. Give each group 3 ceramic tiles, 3 porcelain tiles, one toothbrush and a container of water.
3. Each group should create two copies of the following table: one for the ceramic tiles and one for the porcelain tiles.

Toothpaste Data Table

Toothpaste Brand	Minerals Present	Prediction	Observations

Activity:
1. List all of the ingredients in each toothpaste brand in the first column, and the amounts of each of these ingredients (if listed).
2. Mark each ceramic tile with a black felt-tipped marker.
3. Make predictions on how effective each toothpaste brand will be in removing the marker stain.
4. Put a pea-sized amount of the first toothpaste brand onto the toothbrush. Brush one of the marked ceramic tiles in one direction 50 times. Ensure that students use the same amount of force for each stroke. Record observations in the fourth column. How well did that toothpaste brand remove the stain?
5. Using the container of water, rinse off the toothbrush thoroughly.
6. Repeat steps 4 and 5 with the other two brands of toothpaste.
7. Mark the porcelain tile with a black felt-tipped marker.
8. Repeat steps 3 to 6 with each of the porcelain tiles and toothpaste brands.

Discussion (Length: 10 minutes)

Which brand of toothpaste was the most effective in cleaning the ceramic tiles? What are the active ingredients in that toothpaste brand? Were the students' hypotheses correct?

Why did the experiment include porcelain tiles? Artificial teeth are made of porcelain. Was the same brand of toothpaste also the most effective in cleaning the porcelain tiles?

Discuss the purpose of fluoride in toothpaste. What are the disadvantages of including more fluoride in toothpaste? Discuss the condition called fluorosis in which excess fluoride ingestion can lead to discoloration in developing teeth. This is why toothpaste should never be swallowed and why levels of fluoride in tap water are typically low.

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.

WHAT PARTS OF A COMPUTER ARE MINED?

Description

Students will explore the minerals and metals that are used to make various components of a computer. They will explore the reasons why these materials are useful to computers and extrapolate their findings to other electronic devices.

VOCABULARY:

1. Minerals
2. Properties

MATERIALS:

- *Ground Rules* film
- Resource books or access to the internet

Introduction (Length: 15 minutes)

Watch Chapter 3 "Mining and the Modern World" of the *Ground Rules* film. Discuss the importance of minerals in our daily lives. Minerals have specific properties that make them useful to humans. All minerals come from the Earth's crust and must be mined.

Ask them to recall how many minerals are used in a computer (mentioned on the film). Ask them if they can name any minerals used in a computer and why they think those minerals were useful for the purposes of building a computer. Discuss the fact that minerals have specific properties that make them useful for certain functions. If we want to build something, we must carefully choose the specific minerals that will provide the functions required.

Activity (Length: 45 minutes)

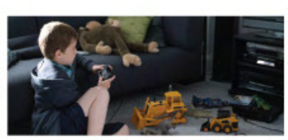
The objective of this activity is to determine the minerals and metals that are used to make a computer and to determine the properties of these elements that are useful for computers.

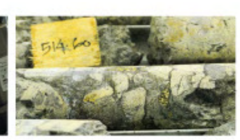
1. Divide the class into groups of 3 to 4 students.

2. Using resource books or the internet, have each group identify the minerals and metals used to build the following components of a computer:

    a. Computer monitor
    b. Computer chip
    c. Computer circuitry
    d. Computer case
    e. Electrical cords





3. Identify the properties of each material that makes it useful to the function of that component of the computer.

Discussion (Length: 30 minutes)

Review the answers and make a comprehensive class list of the minerals and their useful properties. Based on that list, ask the class to hypothesize what minerals would be useful for another electronic item, such as a television, portable media player, cell phone, etc.

Discuss the environmental implications of disposing of outdated computer equipment. Should computer equipment be disposed in a landfill? Why is computer waste one of the biggest waste issues facing the world?

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.

Minerals and Metals in a Computer

Computer Monitor:
- Silicon, lead, strontium, phosphorus, boron, indium, barium

Computer Chip:
- Silicon, gallium

Computer Case:
- Calcium carbonate, clays, mica, talc, sulfur

Computer Circuitry:
- Gold, aluminum, lithium, chromium, silver, nickel, gallium, lead, zinc, copper, steel, tungsten, titanium, cobalt, germanium, tin, tantalum

Electrical cords:
- Copper

GROUND**RULES**

MINERALS AND REAL LIFE

Minerals and Everyday Life

AGES 15-18

GROUNDRULES

MINERALS AND EVERYDAY LIFE | AGE: 15 TO 18 | LENGTH: 1.5DAY | CURRICULUM: earth science, minerals

CONSUMPTION OF MINERAL RESOURCES

Description

Students will learn how dependent they are on mineral resources from mines by keeping a list of all the items they use at home in a day and determining which minerals are used in these items.

VOCABULARY:

1. Minerals
2. Non-renewable resource
3. Consumption

MATERIAL:

- *Ground Rules* film
- Paper and pencils

Introduction (Length: 15 minutes)

Watch Chapter 3 "Mining and the Modern World" of the *Ground Rules* film. Discuss the importance of minerals in our daily lives. Minerals have specific properties that make them useful to humans. All minerals come from the Earth's crust and must be mined.

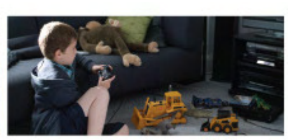
As shown in the film, a variety of minerals are used to make common household items. Recall a few examples of household items mentioned in the film. What minerals were used to make them? Ask the students how many minerals they think they might use in a day.

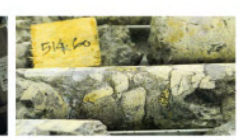
Activity (Length: 1 day + 60 minutes)

The objective of this activity is to learn about consumption of mineral resources in our everyday lives.

1. Each student should make two hypotheses prior to this activity: how many minerals they think they use in a day; and which minerals they think they use most often in a day.
2. Over a 24 hour period, each student should keep a list of all the items he/she uses.
3. They should then identify some of the minerals used to make each of those items.
4. Each student should determine the number of different minerals he/she used in a day and the five most common minerals used in a day.





Discussion (Length: 45 minutes)

Create a summary table on the blackboard. Have the students help generate the column of items used in a day by recalling some of the items on their list. As a class, identify the minerals used to make each of these items. Once a complete list has been generated, ask each student to come up and place a check mark beside all of the items they used in a day. What were the most popular items used? Which minerals were used most often? How many different minerals were used by the class during a 24 hour period? Discuss how the results compared to the student hypotheses. Did students overestimate or underestimate their consumptive habits?

Discuss the implications of their findings. How dependent are we on mined minerals? Are these renewable or non-renewable resources? As long as we continue to use these items in our daily lives, we will be dependent on mining. How will we be able to sustain our consumptive habits in the future?

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.

LIFECYCLE OF COAL

Description

Students will explore the benefits and impacts of coal. They will research the new technologies of methane capture, liquid gasification and carbon capture/sequestration, which are designed to reduce greenhouse gases generated by coal combustion.

VOCABULARY:

1. Coal-fired power plants
2. Coal combustion products
3. Methane capture
4. Liquid gasification
5. Carbon capture and sequestration
6. Non-renewable energy
7. Renewable energy

MATERIAL:

- *Ground Rules* film
- Resource books or internet access

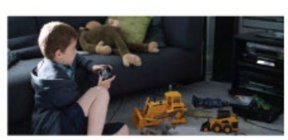
Introduction (Length: 15 minutes)

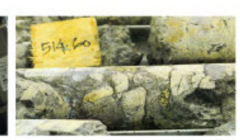
Watch Chapter 8 “Reclamation” of the *Ground Rules* film. This chapter shows how coal is mined at a mine site in the United States and how the site is reclaimed after mining.

What is the major use of coal? Discuss our dependence on coal as an energy source. As the film states, approximately 40% of the world’s electricity is generated by coal. What are some of the benefits and impacts of coal consumption?

Explain that the students will be conducting a research project to learn more about the benefits and impacts of coal to their everyday lives.





Activity (Length: 120 minutes)

The objective of this activity is to learn about the benefits and impacts of coal usage in everyday life and about the technologies that are being used now or may be used in the future to reduce the environmental impacts of coal combustion.

1. Using resource books or internet access, answer the following questions:

    a. What are the benefits of coal to our everyday lives? List several current and historical uses of coal. Which countries are the most dependent on coal as an energy source today?

    b. Describe the process of coal combustion used in a typical coal-fired power plant. What are the impacts of coal combustion?

    c. What are the solid combustion products left over after combustion of coal? Which of these combustion products can be recycled or reused? Which of these products can be disposed in a landfill?

    d. What substances are released to the air during coal combustion? What types of pollution control technologies are used in coal-fired power plants to reduce air pollution and acid rain?

    e. Briefly describe the processes of methane capture, liquid gasification and carbon capture/sequestration. How can these processes be used to reduce greenhouse gas emissions from coal combustion?

    f. How dependent are you on coal combustion? What is the energy source used to generate the electricity you use on a daily basis? Where is the electricity generation facility located? Is this a renewable or non-renewable energy source?

Discussion (Length: 45 minutes)

Review the answers to the questions. Discuss some of the new technologies for reducing the impacts of coal combustion.

<u>Methane Capture:</u>
Methane is stored in large quantities in coal deposits. When these deposits are mined, the methane gas is released to the atmosphere. Methane gas is a potent greenhouse gas (21 times the global warming potential as carbon dioxide). Methane can be captured and directed to a flare where it is burned off or it can be used as fuel to generate power at the mine site. Either way, when methane is burned, it produces two molecules of water and a molecule of carbon dioxide. So, greenhouse gases are still produced, but in the form of carbon dioxide which is less potent than methane.

<u>Liquid Gasification:</u>
In this process, coal is converted to a liquid product. The solid coal is put into a gasifier where heat, pressure and oxygen break up the coal and produce a gas containing carbon monoxide and hydrogen (often called "syngas"). The syngas is then condensed into a liquid

product that can be used to make liquid fuels like diesel and gasoline. Carbon dioxide is released when the coal is liquefied and again when the synthetic fuels are burned.

Carbon Capture and Sequestration:
In this process, carbon dioxide emissions from coal-fired power plants are captured and transported by pipeline to suitable storage facilities. In geological sequestration, the carbon dioxide is injected into certain types of underground geological formations that would essentially trap the carbon dioxide and prevent it from releasing to the surface. Carbon dioxide is also sometimes injected into oil fields to enhance the recovery of oil. It can also be injected into un-minable coal deposits where it adsorbs strongly to the surface of the coal. Sequestration in the oceans is also a possibility, but there may be many undesirable environmental effects with this method. Sequestration of carbon dioxide in mineral formations is currently being studied. Carbon dioxide can be reacted with minerals that contain magnesium and calcium to form carbonates, which are stable and unlikely to re-release the carbon dioxide. However, the natural formation of carbonates is a slow process, so researchers are studying ways to enhance the speed of the process.

Research is still being conducted on all of these technologies to find ways to further reduce emissions of greenhouse gases from coal combustion.

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

MINERALS AND EVERYDAY LIFE

AGE: 15 TO 18

LENGTH: 2.5HR

CURRICULUM: earth science, minerals

MINERAL DESIGN

Description

Students will use the information they have learned about the properties of some common minerals to design a new "invention". They will select the minerals that will be used in the design based on the desired structure and functions of the invention.

VOCABULARY:

1. Mineral properties
2. Structure
3. Function

MATERIAL:

- *Ground Rules* film
- Resource books or internet access (mineral property information)
- Optional: list of potential "inventions"

Introduction (Length: 15 minutes)

Watch Chapter 3 "Mining and the Modern World" of the *Ground Rules* film. Discuss the importance of minerals in our daily lives. Minerals have specific properties that make them useful to humans. All minerals come from the Earth's crust and must be mined.

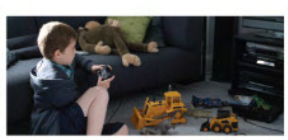
As shown in the film, a variety of minerals are used to make common household items. Recall a few examples of household items mentioned in the film. Why were those minerals selected? What properties of those minerals made them useful for the purpose of creating that item?

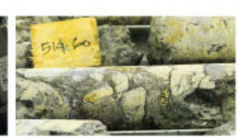
Activity (Length: 90 minutes)

The objective of this activity is to use the information they have gained about mineral properties to design a new invention.

1. Prepare a list of "inventions" the students might choose to design or allow the students to choose their own "invention".
2. Divide the class into groups of 2 or 3 students.
3. Each group should begin by sketching a design of their invention and describing the physical structure and primary functions of the invention.
4. They should determine which minerals they will need to incorporate into the invention to perform the required functions and which minerals they will be required in the physical structure of their invention.
5. Each group should make a presentation to the class, describing their invention, which minerals would be used to create the invention, and why these minerals were selected.





Discussion (Length: 45 minutes)

Have each group present their "invention" design to the class. How could these designs be improved? Did any of the groups miss an important mineral which would have been essential to the structure or function of their invention? Which minerals were most commonly used among the groups?

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.

MINERALS IN MY HOUSE

Description

Students will play a matching game to learn what minerals are used in common household items. They will describe the lifecycle of one key mineral used to make a common household item.

VOCABULARY:

1. Minerals
2. Properties
3. Lifecycle
4. Recycling

MATERIALS:

- *Ground Rules* film
- Sets of "mineral content" cards
- Masking tape
- Resource books or access to internet

Introduction (Length: 15 minutes)

Watch Chapter 3 "Mining and the Modern World" of the *Ground Rules* film. Discuss the importance of minerals in our daily lives. Minerals have specific properties that make them useful to humans. All minerals come from the Earth's crust and must be mined.

As shown in the film, a variety of minerals are used to make common household items. Recall a few examples of household items mentioned in the film that will not be used in the activity. Why were those minerals selected? What properties of those minerals made them useful for the purpose of creating that item?

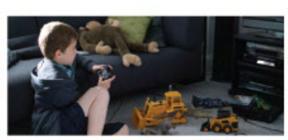
Activity I (Length: 60 minutes)

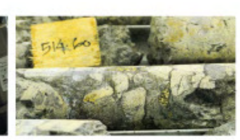
The objective of this activity is to determine the mineral content of common household items.

Preparation:
1. List 10 common household items on the board.
2. Prepare a set of cards containing the minerals used to make those 10 items. One mineral should be written on each card.

Activity:
1. Place all the mineral cards face down on a desk near the blackboard.
2. One at a time, have each student come up to the board, pick a card from the pile and attach it with masking tape beside the household item they think contains that mineral. Remind the class that several minerals may be used in one item.
3. Repeat #2 until all the mineral cards are used.





4. Go through each item and ask the class if the minerals placed beside it are correct. Invite students to come up to the board to correct any mistakes.
5. Continue #4 until the class thinks they have everything correct.
6. Review the correct answers with the class.

Activity II (Length: 60 minutes + writing and presenting time)

The objective of this activity is to describe the lifecycle of the key minerals used to make one household item. Students will determine how and where the minerals are mined, how they are processed, and how they can be recycled or disposed of after use.

1. Divide the class into groups of 2.
2. Using the list generated in Activity I, ask each group to select one household item for further research.
3. Using resource books or the internet, have students conduct research on the minerals used to make that item. They should identify how and where the minerals are mined, how they are processed, and how they can be recycled or disposed of after use.
4. Each group should write a short report on their findings and present it to the class.

Discussion (Length: 15 minutes)

<u>Activity I:</u>
Pick one or two of the items for further discussion. For each item, ask the class why they think those specific minerals were used to make the item. What are the properties of those minerals that make them useful to the household item? Discuss the lifecycle of the minerals used in those items. Where in the world are those items mined? Ask the class if the item can be disposed in a regular landfill after its useful life. Can some of the minerals be separated from the item and recycled?

<u>Activity II:</u>
Have each group present their findings to the class. Discuss the lifecycle of minerals from mining to recycling or disposal. Are mined resources renewable or non-renewable? Can mineral resources be conserved?

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.

Household Items and Minerals (from Chapter 3 of Ground Rules)

Wallboard – gypsum, clay, perlite, vermiculite, aluminum hydrate, borates
Paint – titanium dioxide, kaolin, calcium carbonate, mica, silica, wollastonite
Glass – silica, quartz, lead, titanium, sodium carbonate
Door Knob – nickel
Speakers – aluminum, cobalt, silver, silica, iron, titanium, graphite, mica, carbon, strontium, neodymium
Plastic – calcium carbonate, talc, wollastonite, barium sulfate, clay, mica
Keys – nickel
Stainless steel – iron, nickel, molybdenum, chrom
Non-stick coating – fluorite
Ceramic tiles – clay, feldspar, fluorite, lithium, silica, talc
Countertop – titanium dioxide, calcium carbonate, aluminum hydrate
Knife – chromium
Table salt – halite, iodine
Sugar – limestone, lime
Toothpaste – calcium carbonate, limestone, sodium carbonate, fluorite, mica, zinc
Cosmetics – calcite, hematite, kaolinite, mica, silica, talc, titanium, zinc
Carpet – calcium carbonate, limestone
Textiles – antimony, feldspar, tungsten
Dish soap – halite, sodium carbonate
Can opener – iron, nickel, chromium, molybdenum
Incandescent light bulbs – tungsten
Window panes – silica, lime, sodium carbonate, calcium carbonate, halite, feldspar
Brick – kaolin, shale, barium, manganese
Jewelry – gold, silver, platinum, diamonds
Soda cans – aluminum

Others

Baby powder – talc
Cement - limestone
Insulation - vermiculite
Matches – sulfur
Sun block – zinc
Thermometer – mercury
Utensils – nickel, iron, silver

GROUNDRULES

MINERALS AND EVERYDAY LIFE

AGE: 15 TO 18

LENGTH:3 HR

CURRICULUM: earth science, mineral uses, lifecycle

WHAT PARTS OF A COMPUTER ARE MINED?

Description

Students will explore the rocks, minerals and metals that are used to make various components of a computer. They will explore the reasons why these materials are useful to computers and they will research the complete lifecycle of some of the minerals.

VOCABULARY:

1. Minerals
2. Properties
3. Lifecycle
4. Recycling

MATERIALS:

- *Ground Rules* film
- Resource books or access to the internet

Introduction (Length: 15 minutes)

Watch Chapter 3 “Mining and the Modern World” of the *Ground Rules* film. Discuss the importance of minerals in our daily lives. Minerals have specific properties that make them useful to humans. All minerals come from the Earth’s crust and must be mined.

Ask them to recall how many minerals are used in a computer (mentioned on the film). Ask them if they can name any minerals used in a computer and why they think those minerals were useful for the purposes of building a computer. Discuss the fact that minerals have specific properties that make them useful for certain functions. If we want to build something, we must carefully choose the specific minerals that will provide the functions required.

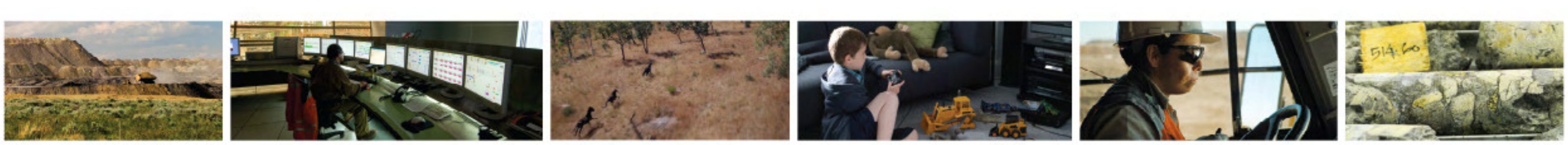
Activity I (Length: 45 minutes)

The objective of this activity is to determine the minerals and metals that are used to make a computer and to determine the properties of these elements that are useful for computers.

1. Divide the class into groups of 3 to 4 students.

2. Using resource books or the internet, have each group identify the minerals and metals used to build the following components of a computer:

   a. Computer monitor
   b. Computer chip
   c. Computer circuitry
   d. Computer case
   e. Electrical cords



3. Identify the properties of each material that makes it useful to the function of that component of the computer.

Activity II (Length: 60 minutes + writing and presenting time)

The objective of this activity is to describe the lifecycle of one mineral used in a computer. Students will determine how and where the mineral is mined, how it is processed, how it is built into the component part required in a computer, and how it can be recycled after use.

1. Using the list generated in Activity I, ask each group to select one mineral for further research.
2. Using resource books or the internet, have students conduct research to identify how and where the mineral is mined, how it is processed, how it is made into the component part required in a computer, and how it can be recycled after use.
3. Each group should write a short report on their findings and present it to the class.

Discussion (Length: 60 minutes)

Activity I:
Review the answers and make a comprehensive class list of the minerals and their useful properties. Based on that list, ask the class to hypothesize what minerals would be useful for another electronic item, such as a television, portable media player, cell phone, etc.

Activity II:
Have each group present their findings to the class. Discuss the environmental implications of disposing of outdated computer equipment. Should computer equipment be landfilled? Why is computer waste one of the biggest waste issues facing the world? Discuss the effort required to disassemble and recycle all of the different components of a computer. It is labor intensive and can also be a health risk if proper health and safety equipment is not used in the process. Discuss the global implications of computer waste. A large amount of computer waste from North America is shipped to China for disassembly and recycling.

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.

Minerals and Metals in a Computer

Computer Monitor:
- Silicon, lead, strontium, phosphorus, boron, indium, barium

Computer Chip:
- Silicon, gallium

Computer Case:
- Calcium carbonate, clays, mica, talc, sulfur

Computer Circuitry:
- Gold, aluminum, lithium, chromium, silver, nickel, gallium, lead, zinc, copper, steel, tungsten, titanium, cobalt, germanium, tin, tantalum

Electrical cords:
- Copper

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