GROUNDRULES

MINING PROCESSES

Mining Processes

AGES 13-15

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: 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.

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

MINING PROCESSES	AGE: 13 TO 15	LENGTH: 1.5HR	CURRICULUM: mass/volume/density, earth science

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.

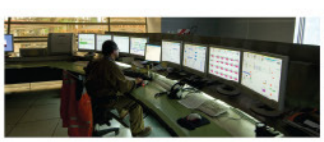
Ask the students if they have ever tried panning for gold. Do they know how it works? How do geologists separate the gold from the water and other rocks, sand and silt? The answer has to do with the properties of mass, volume, density and specific gravity.

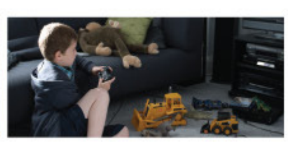
Review the concepts of mass and volume. When we weigh a material, we are determining its mass. When we find out how much space the material occupies, we are determining its volume.

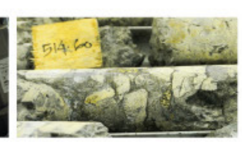
Density is the ratio between the mass and the volume of a material.

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

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.

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

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)

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.

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.

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*.

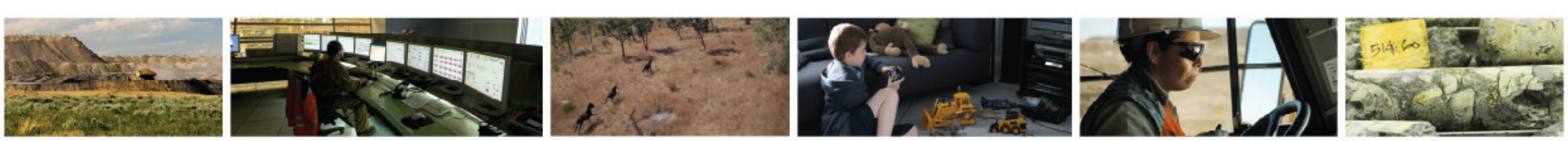
Discuss the stages involved in the development of a metal mine. Emphasize the decision-making processes involved in deciding whether to develop a mine.

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!

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.
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. 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. 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 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.

Phase 5: Mine Valuation:

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

Mineral Revenue:

Gold: __________ poker chips x $400,000 = $ _______________

Copper: __________ poker chips x $20,000 = $ _______________

Total Mineral Revenue (Sum) = $ _______________

Waste Rock Disposal Costs:

__________ 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)	**$**

MINING PROCESSES | AGE: 13 TO 15 | LENGTH: 1.5 HR | CURRICULUM: earth science, mapping, volume/area

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.

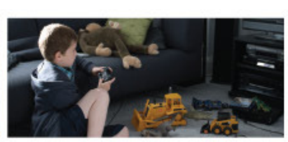
The exploration phase involves identifying an ore body, mapping the location and extent of the ore body, staking a claim, drilling to collect core samples, analyzing the core samples for mineral content and chemistry, and determining whether the property is suitable for mining.

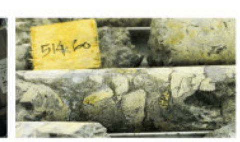
Introduce the concept of costs and benefits. In mining, there are a variety of costs, such as exploration work, regulatory processes, equipment, engineering challenges, mining labor, training, health and safety, and reclamation.

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.

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:

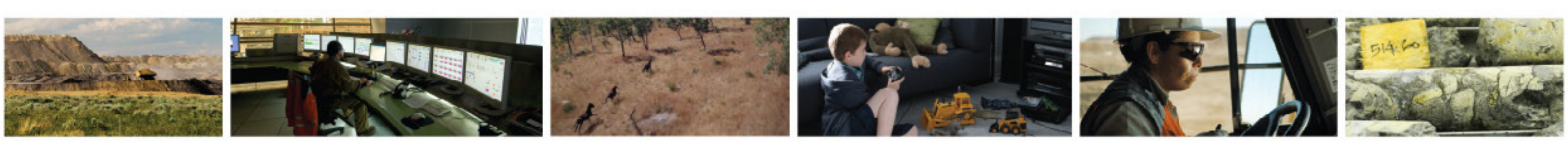
- *Ground Rules* film
- Mixture of gravel, sand and silt (overburden)
- Potting soil
- Bone meal, blood meal and potash, or mixed fertilizer, teaspoons
- Grass seeds
- Water and spray bottle
- Access to sunlight or a lamp
- Shoebox sized plastic tubs, small trowels
- Measuring cups, large mixing bowls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

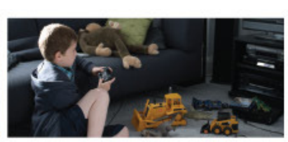
Watch Chapter 2 “Modern Mining” of the *Ground Rules* film.

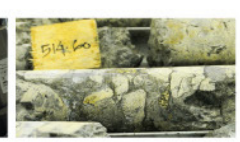
Discuss how simple and complex machines are used to help miners extract mineral from ore. A wide variety of machines are used in the mining process to help miners do their work more efficiently by decreasing the amount of effort and time required to complete tasks.

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:

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

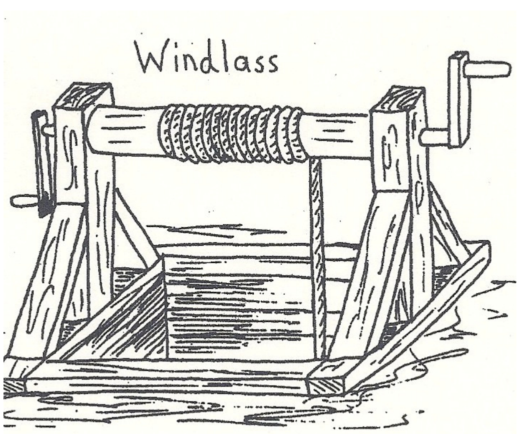
Give an example on the board: If a rock weights 100 lbs (load) and we create a simple machine that requires us to use 50 lbs of our force to lift the rock, then the mechanical advantage of our machine would be 2 (i.e., 100 / 50 = 2). In other words, the simple machine multiplied our effort by 2. It allowed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

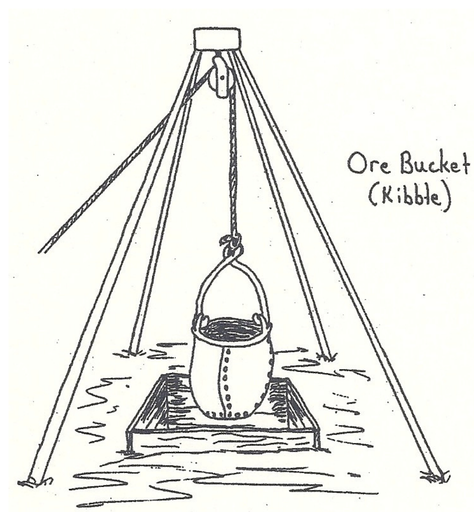
As the mechanical advantage increases, the machine becomes more efficient and less effort is expended by the miner. This allows more work to be done. Engineers can use the mechanical advantage formula to make modifications to existing machines to further enhance efficiency.

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.



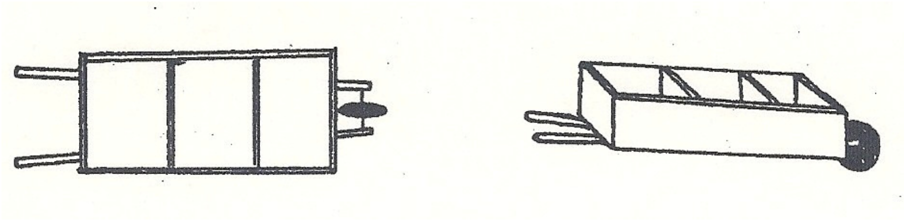


Discuss the two simple machines that make up the wheelbarrow – a lever, and a wheel and axle. The lever helps you lift the load and the wheel and axle helps you move the load. This activity will explore how these two simple machines create mechanical advantage in the wheelbarrow.

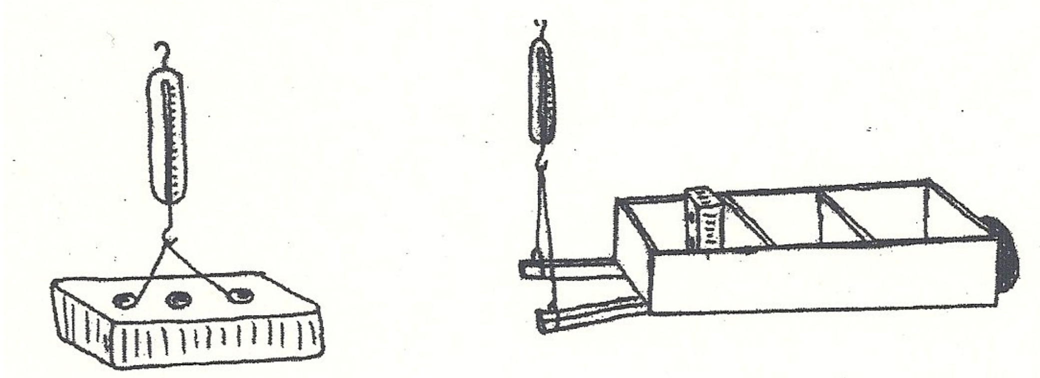
Activity I (Length: 20 minutes)

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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