EdGEO

Canadian Earth Science Teacher Workshop Program

Putting the Earth into Science

In partnership with:

Canadian Geological Foundation · Fondation Géologique du Canada · 1968

Geological Survey Canada · Commission Géologique · 1842

Natural Resources Canada | Ressources naturelles Canada

Contents

Introduction

What is EdGEO

EdGEO is a national program, established in the early 1970s, which supports local workshops designed to give Canadian teachers the knowledge and resources to confidently present Earth science material in the classroom. Local scientists and teachers work together to deliver the workshops. EdGEO can provide grants of up to $3000 per workshop.

EdGEO is a core activity of the Canadian Geoscience Education Network (CGEN) http://www.geoscience.ca/cgen/, which is part of the Canadian Federation of Earth Sciences.

Who is this Resource for?

This resource is directed to teachers of high school chemistry, physics, biology, general science, environmental science and mathematics.

What are the Goals of this Resource?

This resource aims to integrate Earth science topics into the core subjects of physics, chemistry, biology and mathematics. Through an interdisciplinary approach, EdGEO hopes to expand Earth science content in Canadian high schools. The activities offer a meaningful educational experience to students who are often unaware of how Earth science impacts their daily lives.

EdGEO seeks to cultivate in all students a heightened awareness of our planet and an improved capacity to understand the Earth. This will give them an essential foundation to making informed decisions, throughout their lives, about issues underpinned by the Earth sciences, such as the use of mineral and energy resources, the maintenance and remediation of the environment, and response to geological hazards.

Core Subject Connections

In developing the content for this resource, we identified opportunities to include Earth science applications in the curricula from across Canada for the core subjects of biology, chemistry, physics and mathematics. Since overlap exists in skills and content between the curriculum designations, some individual activities can be used in the teaching of more than one core subject. The index table identifies the core subject connections for each activity.

Introduction

Earth Science Literacy Principles

Each activity identifies the fundamental principles about the Earth represented in the task. These describe the large-scale, "big picture" ideas that provide a framework for understanding how the Earth works.

What does each Activity include?

Each activity begins with a teacher's section detailing a summary of the task, the "core curriculum skills" and "Earth science literacy principles" covered. The "Contents" section lists the reproducible student-ready pages that form the activity, and "Teaching notes" describes any advanced preparation needed, hints for classroom delivery or supplementary information. Additional ideas for related learning experiences are given as "Extensions." All activities include "Solutions" to questions on the student pages. The activities contain a variety of student tasks, including experimental investigation, data interpretation, field study and theoretical calculations.

Sponsors

The development and production of this resource was made possible by the generous financial support of the Canadian Geological Foundation.

EdGEO receives ongoing support from:

- Canadian Federation of Earth Sciences
- Canadian Geological Foundation
- Canadian Geoscience Education Network
- Canadian Society of Exploration Geophysicists
- Canadian Society of Petroleum Geologists
- Encana
- Geological Association of Canada, Mineral Deposits Division
- Geological Survey of Canada
- Magma Energy Corp
- Nexen
- Ontario Secondary School Teachers' Federation

Introduction

Safety

As appropriate, individual activities identify specific safety issues and recommend precautions. We have made every effort to ensure that students can carry out these activities safely, under the direction of an experienced teacher. It is the responsibility of each teacher, however, to evaluate the level of risk and to ensure that an activity is suitable for their classroom facilities and students.

Use of Materials and Copyright

The goal for this resource is to produce materials that are available for teachers at no charge through the EdGEO website. Reproduction of these materials for educational purposes is encouraged. Please acknowledge EdGEO as the source. These materials may not be distributed for profit.

Every effort has been made to obtain permission from copyright holders of materials included in the activities. Please contact us if you believe your copyright has been infringed. We welcome any information that will help us credit providers of Earth science education.

Physiology and Habitat

Students carry out a field survey recording the organisms and habitats present in their field area. They observe the physical characteristics of fossils, and interpret their habitat based on similarities to living organisms.

Core curriculum skills

Use of field guides and keys to identify organisms

Physical adaptations in organisms to their environment

Comparing modern and ancient environments

Earth science literacy principles

Information and observations of the present-day Earth are used to understand past events

Earth is a dynamic entity that changes over time, including its climate and environment

Evidence of the Earth's past environment and climate is recorded in many places, including the fossil record

Contents

"Physiology and Habitat" field study

"Living in the Past" investigation

Teaching notes

1. a) Before taking students into field, carry out a risk assessment of the study area. Identify any potential hazards such as water bodies, animals, poisonous plants, traffic, and unstable or steep slopes. Mark out the field area boundaries. Bring a first aid kit and a communications device. Arrange for backup adult supervision and emergency transportation.

   b) "Physiology and Habitat" may be concentrated on one particular habitat or family of organisms, depending on the location available or your teaching focus. For example: the water invertebrates in a pond and a corresponding fossil selection.

2. a) "Living in the Past" can be linked directly to the field study environment by using the live organisms observed, as the comparison for the fossils. It may also be a stand-

alone task, using field guides as reference and a selection of available fossils.

b) Create a base map showing the locations where each fossil was found, and have students interpret the large-scale distribution of ancient habitats. See Resources for an example showing a group of fossils that indicate land and water. Discuss that this is a simplistic interpretation since after the organisms died they may have been transported before being fossilized.

Extensions

- Research the Burgess Shale, a Canadian UNESCO World Heritage Site. It is famous for its unique fossils, in which the soft parts of the organisms, usually lost during fossilization, have been preserved.
- Investigate fossilization methods: moulds, casts, petrifaction and trace fossils.

Resources

Living in the Past - Example of Base Map

	Echinoderm			Petrified wood		
						Amber
Trilobite		Water snail	Leaf	Land snail		
						Turtle shell
	Bivalve		Shark tooth			
					Dinosaur bone	

Legend

Land	(shaded)
Water	(unshaded)

Interpretation of Environment for Fossils on the Base Map

- Echinoderm: marine, shallow water
- Trilobite: marine, shallow water
- Bivalve: marine, shallow water
- Water snail: marine, shallow water
- Shark tooth: marine, shallow water
- Leaf: land
- Land snail: land
- Dinosaur bone: land
- Turtle shell: land
- Amber: land
- Petrified wood: land

Solutions to student activity

Living in the Past

1. Where do you think the fossils were formed? This is not necessarily the same place where the organism lived.

   Answers will vary, students should identify relationship of organism to sediments.

2. What happened to the organisms to allow them to become fossils?

   Answers will vary, may include: death, washed into sea, buried with sediment, dried out, hardened.

3. In what ways are the fossils similar and different to the living organisms?

   Answers will vary, may include that they are a similar shape and size, but that the fossils may not show the whole organism, colour, details of skin, fur, hair, feathers, petals, etc.

4. What components or features are missing from the fossils, but present in live organisms?

   Anything soft or fragile that would not survive the fossilization process.

5. What kinds of features of an organism would be good candidates for fossilization?

   Hard material like shells, bones or teeth.

6. Pick one living organism from your field study and make a detailed sketch of its characteristics.

Dependent on organism chosen.

7. Make a second sketch representing what you think it would look like when preserved as a fossil.

   Answers will vary, may include soft parts missing, lack of colour, distortion of shape.

8. List some living organisms that would be unlikely to be preserved as fossils.

   Answers will vary, examples are worms, butterflies, roses, grass.

Physiology and Habitat Field Study

Materials

Field guides for plants, trees, animals, insects
Measuring tape
String and pegs
Thermometer
Shovel
Net
pH test materials
Water test kit (if applicable)
Tweezers
Magnifying glass

Safety

Wear suitable clothing and shoes for field work.
Be prepared for all weather, including heat, cold and wet.
Stay within the defined field study area.
Do not enter any water body without approval and supervision.
Do not touch, taste or damage the plants and wildlife.
Work in groups of at least three.
Report any accidents immediately to the supervisor.

Procedure

1. Mark out your designated study area using the string and pegs. It should be 5 m x 5 m square. Divide the area into a 1 m x 1 m grid.
2. Complete a site overview of your study area using the template provided.
3. Choose 3 grid squares that represent a range of habitats. Complete an organism survey of selected plots from your study area using the template provided.
4. Choose one organism and complete a case study for its physiology and living environment using the template provided.
5. Identify any physical characteristics of all the organisms you have observed that are unique to each environment in the study area. For example, land mammals have legs.

Site Overview

Plan

	1	2	3	4	5
A					
B					
C					
D					
E					

Profile

Show elevation changes along one side of the survey area.

Legend for Site Plan and Profile

Use colours and symbols to identify each characteristic.

Add additional categories and specific species as required.

Vegetation		Evidence of Life	
Moss Grass		Droppings	
Bushes		Rubbing	
Trees		Tracks	
Submergent water plants		Eaten plants	
Floating water plants		Actual sighting (note species)	
Vegetation Height		**Water Bodies**	
< 10 cm		Salt	
10 cm – 25 cm		Fresh	
25 cm – 1 m		Flowing	
1 m – 5 m		Stationery	
> 5 m		Deep	
		Shallow	
Canopy Cover from Trees		Water Bottom	
< 10 %		Silt	
10 % – 30%		Sand	
30% - 60 %		Gravel	
> 60 %		Pebbles	
		Boulders	

Organism survey

Survey Grid Location:

Physical Environment (add additional characteristics as observed)

Soil		Water	
Colour		Colour	
Texture		Clarity	
Temperature		Flow	
pH		Temperature	
		pH	
		Salinity	

Organisms

Note: to collect invertebrates from:

a) Water: place a net vertically in the water. With your hand, brush off the surface of stones in front of net and remove the stones. Stir up the sediment beneath to dislodge invertebrates toward the net. Sweep the net forward and up to catch organisms disturbed.

b) On land: lift stones, use a shovel to lift vegetation and expose soil.

Type	Number	Habitat where found	Sketch	Physiological characteristics

Case Study: Physiology and Environment

Select one live organism from your field survey and complete the information below.

Scientific Diagram

Use correct nomenclature (use field guide for reference)

Description

Note physiological characteristics

Living Habitat

Based upon physical data collected during the field study and reference materials.

Living in the Past

Materials

Selection of fossils
Map of where the fossils were found
Field guides for plants, animals and insects

Procedure

1. Copy the observation template below.
2. Observe and describe the physical properties of each fossil.
3. Use field guides to identify a present-day living organism with similar characteristics to each fossil.
4. Describe the habitat and environment where the present-day organism lives.
5. Describe the environment where you think the organism that became the fossil lived.
6. Identify the major changes in the environment on the map of where the fossils were found.

Observations

Fossil Name	Fossil Physical Properties	Similar to Living Organism	Living Organism Habitat	Fossil Organism Habitat

Questions

1. Where do you think the fossils were formed? This is not necessarily the same place where the organism lived.
2. What happened to the organisms to allow them to become fossils?
3. In what ways are the fossils similar and different to the living organisms?
4. What components or features are missing from the fossils, but present in live organisms?
5. What kinds of features of an organism would be good candidates for fossilization?
6. Pick one living organism from your field study and make a detailed sketch of its characteristics.
7. Make a second sketch representing what you think it would look like when preserved as a fossil.
8. List some living organisms that would be unlikely to be preserved as fossils.

Tree Growth

Students observe growth patterns as revealed by tree rings and interpret climate variations. They apply their knowledge to a set of simulated tree cores.

Core curriculum skills

Structure of trees

Environmental conditions for tree growth

Measurement

Graphing

Earth science literacy principles

Earth is a dynamic entity that changes over time, including its climate and environment.

Evidence of the Earth's past environment and climate is recorded in many places, including tree growth.

Contents

"Growth Patterns in Trees" investigation

Teaching notes

1. a) Obtain tree cookies (a horizontal slice through a tree trunk) for observation. Oak, ash, and all conifers are recommended as they have distinct rings. Aspen, red maple and birch have less distinct rings. One easily accessed source for cookies is discarded Christmas trees. Lightly sand the surface of the cookies and cores to reveal the rings more clearly. Pencil rubbings make a permanent and easily shared record of a tree cookie.

   b) You can also use an increment borer to take a thin core from the tree, about the diameter of a pencil, which shows the rings and does not damage the tree.

2. Prepare copies of the graphic record of simulated tree cores provided in Part 4 of "Growth Patterns of Trees," sufficient for one per student. The individual tree core strips may be cut apart and laminated for repeated use.

3. When observing the real tree cookies or cores prompt students to look for the channels where fluids can flow.

4. After the activity, facilitate discussion of how tree-ring measurements from large data sets are used as records of past climates. Have students reflect on the environmental factors required to account for the differences they have observed in the tree rings and the statistical requirements for meaningful interpretation.

Extensions

- Carry out a field study of a forest site. Record factors that may affect tree growth, e.g. soil properties and water drainage, and research local history of events relevant to tree growth and climate data. Combine this information with growth data from tree cores and interpret the correlations.
- Investigate factors inhibiting and promoting cell growth in plants, e.g. photosynthesis or nutrient source.
- Apply statistical standardization to the observed tree cookie data to remove effects of individual growth patterns.
- Research uses of cellulose, the material that makes up tree cells.

Solutions to student activity

Growth Patterns in Trees

Part 1: Observations

1. Describe your observations: What shape are the rings? Is the pattern uniform? Are all rings continuous? Are all the rings the same thickness? What textures can you see in different parts of the tree?

   Rings alternate between dark and light bands, which may be of varying thickness. Not all rings will be complete circles.

2. Why does the width of the rings vary?

   Ring width represents the annual growth of the tree, which is controlled mainly by temperature and rainfall. Growth is also affected by soil conditions, floods, drought, insect attacks, forest fires, lightning strikes, volcanic activity, irrigation changes, pollution, and light competition from other trees or buildings.

3. Which are the youngest rings and which are the oldest?

   The only living part of the tree is the outer layers where new bark and wood grows. The youngest rings are on the outer edge of the tree and the oldest are in the centre.

Part 3: Analysis

1. What is the overall pattern of growth throughout the life of this tree?

   This will depend on the sample. Typically, the rings get narrower as the tree gets older and the percentage of total growth each year declines.

2. Which year had the best growing conditions? Which had the worst?

   Again, this will depend on the sample. Students should identify the year with the largest percentage of growth as the best, and the smallest percentage as the worst.

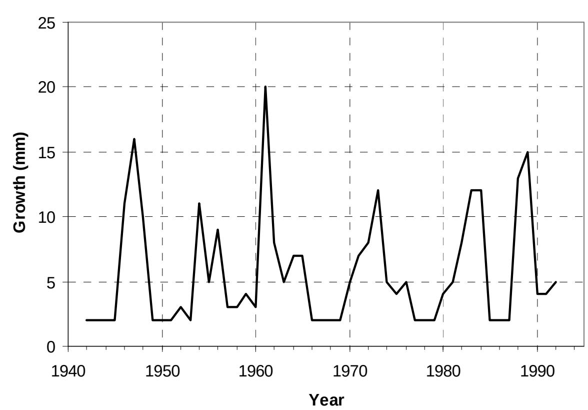
3. What, if any, conclusions can you make about the climate during the life of this tree?

   All tree rings are indirect evidence of climate changes, but large-scale interpretation from one tree is limited because there are so many factors involved. Combining data sets from multiple trees, however, is a very valuable record of climate changes.

Part 4: Application

Sample Number	Age	Year Cut	Year Growth Started
1	31	1993	1962
2	28	1990	1962
3	39	1988	1949
4	28	1970	1942

4. Plot a graph showing the annual growth shown by the combined record of the 4 samples from this woodlot.



5. Identify years where the tree rings reveal the climate experienced:

   a) drought

   1942 to 1945

   1949 to 1953

   1957 to 1960

   1960 to 1969

   1977 to 1979

   1985 to 1987

   b) high rainfall

   1947, 1961, 1954, 1956, 1973, 1983, 1984, 1989, 1988

Growth Patterns in Trees

Materials

Tree cookies or cores
Hand lens or specimen microscope
Ruler
Graph paper
Scissors

Part 1: Observations

1. Use a hand lens or microscope to study your tree cookie or core.
2. Describe your observations: What shape are the rings? Is the pattern uniform? Are all rings continuous? Are all the rings the same thickness? What textures can you see in different parts of the tree?
3. Why does the width of the rings vary?
4. Which are the youngest rings and which are the oldest?
5. Make a sketch of the cookie, labelling the parts of a tree as described below:

   outer bark protects the tree's sensitive living tissues from weather, animals, insects, fungi, etc.

   inner bark is where you find the phloem cells that carry nutrients produced by the leaves to living tissue elsewhere in the tree

   cambium is beneath the bark, and contains the reproductive tissue that produces new wood and new bark

   springwood has large, thin-walled cells that are light in colour. These cells grow rapidly at the beginning of each growing season

   summerwood has small, thick-walled cells that are dark in colour. These cells grow more slowly as summer progresses

   sapwood is created when the new wood dies, but it still serves as a transport route for water from the tree's roots to its crown

   heartwood is at the centre of the tree. These older, dead cells mainly provide support to the tree

Part 2: Measurement

Most trees grow two annual rings: one in the spring, which is light in colour, wider and contains thinner-walled cells; the other ring, grown in the summer, is darker and has thicker-walled cells.

1. How old was this tree when it was cut to make your tree cookie or core?
2. Plot a graph showing the radius of the tree against its age.

3. Calculate the percentage growth each year and add this to your graph.

Part 3: Analysis

1. What is the overall pattern of growth throughout the life of this tree?
2. Which year had the best growing conditions? Which had the worst?
3. What, if any, conclusions can you make about the climate during the life of this tree?

Part 4: Application

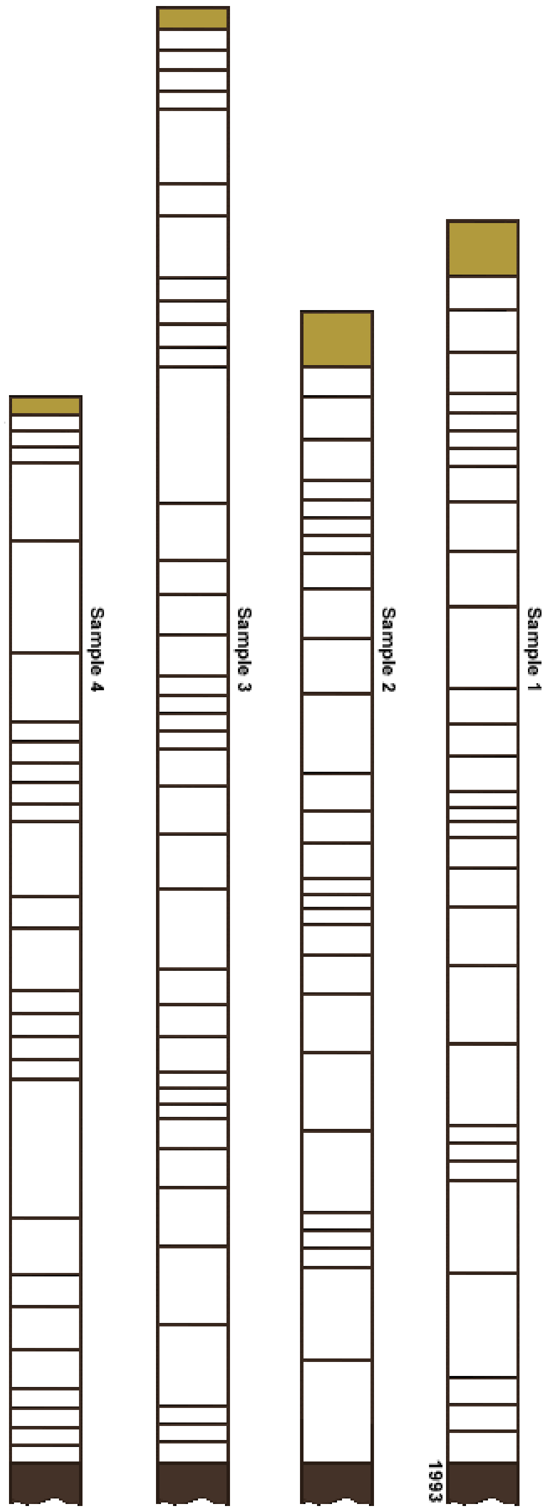
You are provided with the graphic records of 4 tree cores from the same woodlot. Each black line represents the end of the annual growth cycle, which includes the spring and summer rings. Sample 1 was cut in 1993, but the other samples are of unknown age. These records are from the U.S. Geological Survey (USGS).

1. Count the rings to find out the age of each sample.
2. Match the patterns in the growth rings to establish which year each sample was cut.
3. Deduct the age from the year each sample was cut to calculate when growth started.
4. Plot a graph showing the annual growth shown by the combined record of the 4 samples from this woodlot.
5. Identify years where the tree rings reveal the climate experienced:

   a) drought

   b) high rainfall

Sample Number	Age	Year Cut	Year Growth Started
1		1993	
2			
3			
4			



Source: USGS

The Water Cycle

Students measure transpiration from a plant and extrapolate this to the effects of forests on climate. They build a model aquifer and investigate natural and human influences on the water table and on stream flow, including how contaminants spread through the water cycle.

Core curriculum skills

Transpiration from plants

Water cycle

Environmental contaminants

Measurement: area, weight, volume

Estimation

Earth science literacy principles

The Earth is a complex system of integrated and interacting subsystems, including the water cycle.

Plants and trees are a major part of the water cycle. They absorb water through their roots and transpire large volumes of it into the atmosphere.

Human activities can affect the Earth's natural systems, including groundwater resources, even ones at a distance.

Understanding Earth systems can help mitigate the negative effects of human activities.

Contents

"Water from Plants" investigation

`Water in the Ground" investigation

Teaching notes

1. When students have completed the "Water from Plants" investigation, share with them that transpiration from plants and evaporation of moisture from rivers and streams, etc., on land provides two-thirds of the water in the Earth's atmosphere. Evaporation from the vast ocean surfaces accounts for only one-third of atmospheric moisture. Atmospheric moisture falls as precipitation and is a major factor in global climate.

2. a) Flat-sided juice bottles are well-suited for building the model aquifer for "Water in the Ground." Round bottles can be substituted and stabilized with clay or card supports to stop them rolling.

   b) If students are not familiar with the concepts of porosity and permeability, show them a simple demonstration using a jar filled with marbles. Ask them if the jar is full? Add water to fill the spaces between the marbles. This is exactly what happens between the particles of rocks in an aquifer.

Extensions

- Investigate transpiration from different types of plants and trees, and how this relates to their habitat.
- Build a complete closed-system terrarium: soil, plants, water and organisms, and allow it to reach equilibrium over a few weeks.
- Investigate porosity and permeability, and how the properties of different rock types can be used in hazardous waste disposal.

Solutions to student activities

Water from Plants

1. Where does the moisture come from that collects in the top cups?

   It is released from the plant leaves.

2. Imagine that your plant was a large tree with many times more leaves. Assume that this tree transpires just like your plant. Estimate how much water it would transpire over one day.

   Answers will depend on parameters chosen.

3. If this tree was in a small forest with 1000 such trees, how much water would transpire from the whole forest?

   Answers will depend on question 2; a multiple increase of 1000.

4. How might the amount of water coming from the forest affect the local climate?

   Atmospheric humidity and chances of precipitation are increased.

Water in the Ground

Part 1: Building a Model Aquifer

1. What happens to the water table, the stream and the well when there is no rain?

   The aquifer is not recharged, the water table and well level drops, and the stream runs dry.

2. What happens to the water table, the stream and the well when groundwater is consumed, for example, by agriculture, industry and residential homes?

   More water is removed from the aquifer than is being replaced, the water table lowers, and the stream runs dry.

Part 2: Contaminant Paths

1. Describe how the contaminant spreads through the groundwater in your model.

   The contaminant seeps downwards into the water table and spreads in all directions. When there is a stream flow, the contaminant is spread downstream and into the ocean.

2. What effect does the sphagnum moss have on the spread of the contaminant?

   The wet sphagnum moss traps the contaminant and protects the aquifer.

3. How does the impermeable layer of Plasticine affect the spread of the contaminant?

   It protects the aquifer below by directing and containing the contaminant.

4. How can we use knowledge of the properties of rocks to help with the disposal of hazardous waste?

   Impermeable rocks can contain water-borne hazardous waste, for example, runoff from landfills.

Water from Plants

Plants and trees absorb water primarily through their roots. About 1% of the water they absorb is used in photosynthesis to provide the nutrients they need to grow. The rest is evaporated through openings in their leaves in a process called transpiration. In this investigation, you will measure how much water a plant transpires.

Materials

1-cm grid graph paper
Small stem cutting from a plant, with leaves
4 clear plastic cups
Plastic wrap
Scissors
Petroleum jelly
Water
Balance scales
Masking tape
Lamp or source of sunlight

Construction

1. Estimate the area of the leaves on the plant stem by gently tracing the shapes onto 1 cm grid graph paper. Be careful not to damage the leaves.
2. Fill one cup with water.
3. Cover the top of the cup with plastic wrap
4. With the scissors, make a small hole the same diameter as the plant stem in the centre of the plastic wrap.
5. Make a fresh cut at the tip of the plant stem and push it through the hole in the plastic wrap. Seal around the hole with petroleum jelly.
6. Weigh a second cup.
7. Invert the second cup and place over the plant stem so that the rims of the two cups align.
8. Seal the two cup rims together with masking tape.
9. Make a second identical set of cups, but with no plant stem.
10. Put the cup structures in the sun or under a lamp.
11. Leave them for at least 15 minutes, overnight if possible.
12. Taking care not to lose any of the water that has collected in the top cups, separate the two cups.
13. Weigh the top cups with the water they contain.

Calculations

Note: At room temperature, 1 g of water has a volume of 1 ml

1 L = 1000 ml

Total area of plant leaves	cm^2
Weight of top cup and water with plant	g
Weight of top cup and water with no plant	g
Initial weight of top cup	g
Weight of water from plant leaves	g
Volume of water	ml
Water loss per square centimetre of leaf	ml/cm^2
Length of time of experiment	min

Questions

1. Where does the moisture come from that collects in the top cups?
2. Imagine that your plant was a large tree with many times more leaves. Assume that this tree transpires just like your plant. Estimate how much water it would transpire over one day.
3. If this tree was in a small forest with 1000 such trees, how much water would transpire from the whole forest?
4. How might the amount of water coming from the forest affect the local climate?

Water in the Ground

Water is stored underground, not in flooded caves or pools, but in the tiny spaces found between particles of porous or fractured rock. This is called groundwater. The level below which all the available spaces in the rock are filled with groundwater is called the water table. An area of saturated rock that can be a supply of usable water is called an aquifer. Groundwater flows through the spaces between the rock particles to lower points, both underground and on the surface, e.g. at springs or lakes. An aquifer is replenished by water flowing in from precipitation on the surface or by an underground flow from other areas. Only about 10% of precipitation will soak into the ground to reach the aquifer; the other 90% is divided evenly between the take up by plants and trees, and surface runoff into rivers and lakes.

Part 1: Building a Model Aquifer

Materials

2-L clear plastic flat-sided bottle with cap, one side cut open
White gravel
Drinking straw
Bucket or dishpan
Water
Blue food colouring
1-L plastic bottle with cap
Masking tape
Pump from a spray bottle; stem thin enough to fit into drinking straw
Plastic cup

Construction

1. Lay the 2-L plastic bottle horizontally, with the cap on and the open side up.
2. Tape a drinking straw halfway along the bottle so that it protrudes vertically out of the open bottle side and rests a few centimetres above the opposite side. This represents a well.
3. Fill the bottle to 2/3 of its depth with gravel.
4. Add water mixed with blue food colouring up to ½ of the gravel depth.
5. Position the bucket or dishpan underneath the cap of the bottle to catch any water that flows out. This is your aquifer model.
6. Pierce a hole in the bottom of the 1-L bottle. Cover the hole with masking tape.
7. Fill the bottle with blue coloured water. Replace the cap and sit the bottle upright on a paper towel. This is your supply of rain.

Normal Flow

1. Hold the rain supply above the end of the aquifer model away from the cap.
2. Open the cap of the aquifer model and let water flow as a stream into the bucket. The bucket represents an ocean.
3. Remove the masking tape and allow rain to fall onto the gravel.
4. As needed, refill the rain supply from water collected in the bucket.
5. Complete the observation table for normal flow state.

Drought

1. Stop any rainfall from falling onto the gravel. Keep the cap of the aquifer open.
2. Complete the observation table for drought state.

Flood

1. Open the cap of the rain supply and rapidly pour in the water to simulate a sudden, violent rainstorm.
2. Complete the observation table for flood state.

Water Consumption

1. Replenish or drain aquifer to normal flow levels as in Part 1.
2. Keep the cap of the aquifer open to allow the stream to flow and have normal rainfall on the surface.
3. Put the stem of the pump into the drinking straw.
4. Pump out water from the well into a plastic cup.
5. Complete the observation table for water consumption state.

Observation Chart

State	Water table level	Well level	Stream flow	Sketch
Normal flow				
Drought				
Flood				
Water consumption				

Questions

1. What happens to the water table, the river and the well when there is no rain?
2. What happens to the water table, the stream and the well when groundwater is consumed, for example, by agriculture, industry and residential homes?

Part 2: Contaminant Paths

Materials

Model aquifer (see "Building a Model Aquifer")
Rain supply
Small plastic cup, e.g. medicine cup or film canister
Masking tape
Bucket or dishpan
Red food colouring
Blue food colouring
Water
Pump from a spray bottle; stem thin enough to fit into drinking straw
Plastic cup
Sphagnum moss
Plasticine

Contaminant Plumes

1. Punch a small hole in the bottom of the small plastic cup and cover it with masking tape.
2. Fill the cup with water dyed with red food colouring. This is your contaminant supply.
3. Fill the aquifer with water dyed with blue food colouring. Open the cap and allow the stream to flow into the ocean, represented by the collecting bucket. Let the stream flow stop when the water table reaches the same level as the mouth of the stream (the bottle cap).
4. Place the contaminant supply on top of the gravel at the end away from the stream. Carefully observe the water table, the well water and the contaminant.
5. Draw a sketch of where the contaminant plume spreads with no stream flow.
6. Use your rain supply to add water to the aquifer and create stream flow.
7. Draw a sketch of where the contaminant plume spreads with stream flow.
8. Put the stem of the pump into the drinking straw in the aquifer model.
9. Pump out water from the well into a plastic cup.
10. Draw a sketch of where the contaminant plume spreads as the groundwater is pumped out through the well.
11. Remove the contaminant supply and flush out the aquifer with blue coloured water until traces of contaminant are negligible.

Natural Filters

1. Make a hollow in the top surface of the gravel, deep enough to reach the water table and create a small pond.
2. Saturate the sphagnum moss with water and place it into the pond to simulate a marsh or wetland.
3. Place the contaminant supply on the sphagnum moss.
4. Observe the aquifer water for signs of contaminant.
5. Use your rain supply to add water to the aquifer and create stream flow.

6. Observe the aquifer water and stream flow for signs of contaminant.
7. Remove the contaminant source and sphagnum moss. Squeeze the moss into the sink and observe the water colour.

Geology

1. Roll Plasticine into a flat sheet half the length of the aquifer model.
2. Scrape off the top few centimetres of gravel. Lay the Plasticine sheet in the bottle and replace the remaining gravel.
3. Place the contaminant supply above the layer of Plasticine.
4. Observe the aquifer water for signs of contaminant.
5. Use your rain supply to add water to the aquifer and create stream flow.
6. Observe the aquifer water and stream flow for signs of contaminant.

Questions

1. Describe how the contaminant spreads through the groundwater in your model.
2. What effect does the sphagnum moss have on the spread of the contaminant?
3. How does the impermeable layer of Plasticine affect the spread of the contaminant?
4. How can we use knowledge of the properties of rocks to help with the disposal of hazardous waste?

Carbon Cycle

Students test a range of physical and organic reactions for the presence of carbon dioxide ($C0_2$). They complete a simulation of a carbon atom moving around the carbon cycle.

Core curriculum skills

Acid and base indicator

Combustion

Respiration

Products and processes of the carbon cycle

Carbon dioxide sources and sinks

Earth science literacy principles

The Earth is a complex system of integrated and interacting subsystems, including the carbon cycle.

Carbon is present in living and inorganic things.

The carbon cycle has multiple and non-linear connections between organisms and the physical environment.

Human activities can affect the Earth's natural systems, including the carbon cycle.

Contents

"In Search of Carbon" investigation

"The Carbon Tour" activity

Teaching notes

1. When reviewing the combustion and respiration processes in the "In Search of Carbon" investigation be clear about the fact that the carbon and hydrogen in our food and candle wax are the minimum contents. We only tested for one product (CO_2).
2. a) Print the location cards for "The Carbon Tour" activity ahead of time. Distribute them around the room with one die at each station. Introduce the students to each station name and location and then allow students to move through each station as the cards instruct.

b) When discussing the students' paths around the carbon cycle, emphasize that carbon is cycling continuously through the Earth's atmospheric, water, rock and life systems. It is found in both the living and inorganic parts of the Earth. To illustrate this, present the relative volumes of each of the transfers. For example, land plants are much more likely to decompose into soil than become coal, and ocean water can absorb much more CO_2 than freshwater.

3. Have students investigate the basic magnetic field patterns and apply this to the Earth in "Looking at Magnetic Fields." To supplement the model Earth, view images of the Earth's magnetosphere at: http://pwg.gsfc.nasa.gov/istp/outreach/theretohere.html

Extensions

- Investigate the relative absorption of CO_2 in salt water and freshwater.
- Create a dramatic production of "The Carbon Tour" illustrating the carbon cycle.

Solutions to student activities

In Search of Carbon

1. Based on your observations, list places on Earth where carbon can be found.

   Food, drink, animals, humans, rocks, air, soil.

2. Where does the carbon in a candle come from?

   Fossil fuels.

3. Your results showed that when we burn a candle, the following combustion process occurs:

   Wax + oxygen > carbon dioxide + water + heat

   Write a chemical equation for this reaction using what we know for oxygen, carbon dioxide and water to infer the elements in wax.

   $CH + O_2 > CO_2 + H_2O + heat$

4. Where does the carbon in our bodies come from?

   Food and drink.

5. Your results showed that when we breathe out, the following respiration process occurs: *food + oxygen > carbon dioxide + water + heat*. Write a chemical equation for this reaction using what we know about the elements

in oxygen, carbon dioxide and water to infer the chemicals in our food.

$CH + O_2 > CO_2 + H_2O + heat$

The Carbon Tour

1. Sketch a diagram to show the path you took through the different stations.
2. Use the definitions above to label the process involved in each journey you took between locations.
3. Will your journey ever end?

   No

4. Look at other students' carbon tours. Were they all the same? Why?

   The paths are different because there are multiple ways carbon enters and leaves each location.

5. What would happen to the path a carbon atom can take if we burned twice as much fossil fuel?

   We would add more CO_2 to the atmosphere.

6. What would happen if we cut down half of the trees?

   More CO_2 would stay in the atmosphere.

7. a) Which locations are carbon dioxide sources?

   Plants and trees, animals, soil, carbonate rocks, oil, coal and natural gas

   b) Which locations are carbon dioxide sinks?

   Plants and trees, freshwater, ocean water, soil.

In Search of Carbon

When carbon reacts with oxygen, it forms carbon dioxide (CO_2) which is easy for us to detect. When CO_2 dissolves in water, it produces carbonic acid. An indicator will show the presence of this acid. In this activity we will use bromothymol blue (BTB), which has a dark blue colour that changes to green, yellow or very pale yellow as the concentration of acid increases.

Materials

2 L pop bottle
25 cm rubber tube
Sealing tape, e.g. duct tape
250 ml Erlenmeyer flask
Bromothymol blue (BTB) solution
Base solution, e.g. ammonia, sodium hydroxide
Eye dropper
250 ml beaker
Baking soda
Vinegar
Can of pop
Crushed limestone or blackboard chalk
Instant yeast
Sugar
Water
Small candle in safe holder
Bicycle pump

Procedure

Part 1: Build a CO_2 Detector

1. Cut the top 20 cm from the pop bottle to create a funnel shape.
2. Insert 2 cm of the rubber tube into the neck of the funnel. Seal the tube to the funnel using tape.
3. Place 100 ml BTB solution into the Erlenmeyer flask.
4. Insert 2 cm of the other end of the rubber tube into the flask neck.
5. Seal the tube to the flask using tape.

Part 2: Investigations

Between each investigation, reset your CO_2 detector by rinsing the funnel with tap water and, if necessary, adding a few drops of your base solution to the BTB to return it to its original colour. Reseal the rubber tube connections.

1. Put on safety goggles.
2. Place 5 ml baking soda in the beaker. Add 25 ml vinegar and quickly place the funnel of your detector over the beaker. Observe the BTB solution for any colour change. Rinse the beaker clean and reset your detector.
3. Open the can of pop and quickly place the funnel of your detector over the can. Observe the BTB solution for any colour change. Reset your detector.
4. Place a small handful of crushed limestone or blackboard chalk in the beaker. Cover it with vinegar. Place the funnel of your detector over the beaker. Observe the BTB solution for any colour change. Rinse the beaker clean and reset your detector.

5. Place 5 ml instant yeast, 5 ml sugar and 20 ml warm tap water in the beaker. Place the funnel of your detector over the beaker. Observe the BTB solution for any colour change. Rinse the beaker clean and reset your detector.
6. Place the candle securely in the centre of the beaker. Light the candle and place the funnel of your detector over the beaker. Observe the BTB solution for any colour change and any other products in the beaker. Rinse the beaker clean and reset your detector.
7. Direct a bicycle pump into the funnel and pump fresh air into the tube. Observe the BTB solution for any colour change. Reset your detector.
8. Breathe into the funnel. Observe the BTB solution for any colour change and any other products in the funnel. Reset your detector.

Results

Investigation	BTB colour	CO_2	Source of carbon

1. Based on your observations, list places on Earth where carbon can be found.
2. Where does the carbon in a candle come from?
3. Your results showed that when we burn a candle, the following combustion process occurs: *wax + oxygen > carbon dioxide + water + heat*. Write a chemical equation for this reaction using what we know about the elements in oxygen, carbon dioxide and water to infer the chemicals in wax.
4. Where does the carbon in our bodies come from?
5. Your results showed that when we breathe out, the following respiration process occurs: *food + oxygen > carbon dioxide + water + heat*. Write a chemical equation for this reaction using what we know about the elements in oxygen, carbon dioxide and water to infer the chemicals in our food.

The Carbon Tour

1. You will act the role of a carbon atom. Go to your first station.
2. Roll the die.
3. Follow the instructions on the location card to see what happens to you and where you go next. Fill in the first line of your tour schedule before you move on.
4. Continue to roll the die and find out what happens to you at each station on your tour.

Tour Schedule

Station Number	Location	What happened to you?
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Continue the tour schedule as needed.

Definitions of Processes

Respiration: organisms release gases.

Photosynthesis: organisms use sunlight to process chemicals into nutrients for growth.

Absorption: liquids or gases soak into solids.

Dissolving: solids and gases mix into a liquid.

Lithification: materials are buried, compacted and cemented into a rock.

Combustion: materials are burned using heat.

Weathering: solids are broken down by natural elements.

Consumption: organic substances are eaten and used up.

Decomposition: organic material decays.

Questions

1. Sketch a diagram to show the path you took through the different stations.
2. Use the definitions above to label the process involved in each journey you took between locations.
3. Will your journey ever end?
4. Look at other students' carbon tours. Were they all the same? Why?
5. What would happen to the path a carbon atom can take if we burned twice as much fossil fuel?
6. What would happen if we cut down half of the trees?
7. The locations for your carbon tour are different products of the carbon cycle.

   A **carbon dioxide source** releases CO_2 into the atmosphere and may be living, dead or non-living.

   A **carbon dioxide sink** absorbs and holds CO_2 from the air or water.

   a. Which locations are carbon dioxide sources?

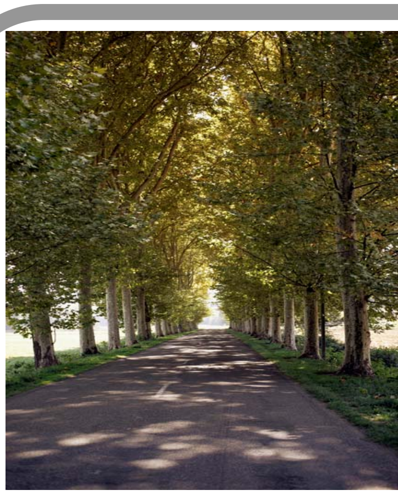
   b. Which locations are carbon dioxide sinks?

Atmosphere

Roll Die	What happens to you
1, 4	The CO_2 you are in is absorbed by photosynthesis to produce carbon in **land plants and trees**.
2, 5	You have dissolved into **rainwater**.
3, 6	You stay in the **atmosphere** a little longer.

EdGEO

Land plants and trees



Roll Die	What happens to you
1	The plant you are in died. You are decomposed and become part of the **soil**.
2	You are breathed out as CO_2 to the **atmosphere**.
3	The plant you are in is eaten by a **land animal**.
4	The plant you are in is eaten by a **marine animal**.
5	The plant you are in is burnt and you are released as CO_2 to the **atmosphere**.
6	The plant you are in is buried, compacted and over many years in the rock cycle becomes **coal and natural gas**.

EdGEO

Land animals

Roll Die	What happens to you
1	The animal you are in dies. You are decomposed and become part of the **soil**.
2, 6	You are breathed out as CO_2 to the **atmosphere**.
3	The animal you are in is eaten by another **land animal**.
4	The animal you are in is eaten by a **marine animal**.
5	A tsunami washes the land animal you are in out to sea. The animal dies, decomposes and you become part of the **ocean water**.

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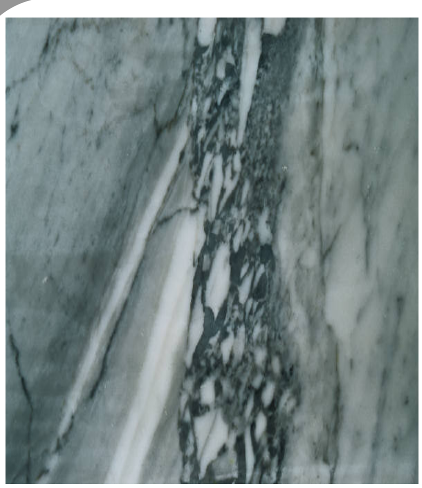
Ocean water

Roll Die	What happens to you
1, 5	You are absorbed by **marine animals**.
2, 6	You are absorbed by **marine plants**.
3	You are precipitated out of the ocean water and after many years in the rock cycle, become a **carbonate rock**.
4	You stay in the **ocean water** a little longer.

Marine animals

Roll Die	What happens to you
1, 5	The animal you are in died and the soft parts are buried, decomposed and over many years in the rock cycle become **oil**
2, 6	The animal you are in died and the carbonate hard parts are buried, and after many years in the rock cycle become **carbonate rock**.
3	The marine animal you are in is eaten by a **land animal**.
4	You stay in the **marine animal** a little longer.

Carbonate rocks



Roll Die	What happens to you
1, 5	The limestone you are in is weathered and you are released as CO_2 to the **atmosphere**.
2	The dolostone you are in is weathered and you are washed into the **ocean**.
3	The chalk you are in is metamorphosed by heat into marble, a **carbonate rock**.
4, 6	The rock you are is melted and erupts from a volcano. You are released as CO_2 into the **atmosphere**.

Soil

Roll Die	What happens to you
1, 4	Rain falls on the soil you are in and you become part of **freshwater**.
2, 5	You are released as CO_2 to the **atmosphere**.
3, 6	The soil you are in is weathered and you are released as CO_2 to the **atmosphere**.

Rain

Roll Die	What happens to you
1, 4	You fall into a lake or stream and become part of **fresh water**.
2, 5	You fall on the land and become part of the **soil.**
3, 6	You rain over the sea and become part of **ocean water**.

Fresh water

Roll Die	What happens to you
1, 5	You are absorbed by **land plants**.
2, 6	You are absorbed by **land animals.**
3	You **are** absorbed by the **soil.**
4	You flow down a river and pass into **ocean water.**

Oil

Roll Die	What happens to you
1, 4	The oil you are in is burnt and you are released as CO_2 in the **atmosphere**.
2, 5	The oil you are in is refined to **petrochemical products**.
3, 6	You stay in the **oil** a little longer.

Petrochemicals

Roll Die	What happens to you
1, 5	The plastic bottle you are in is recycled and becomes a new **petrochemical product**.
2, 6	The synthetic fabric you are in is put in a landfill, and stays as the same **petrochemical product**.
3	The rubber you are in is burnt at high temperature and you are released as CO_2 to the **atmosphere**.
4	The fertilizer you are in is used on a garden and you are absorbed into the **soil**.

Coal and natural gas

Roll Die	What happens to you
1	The coal you are in is weathered and you are released as CO_2 to the **atmosphere**.
2, 5	The coal you are in is burnt and you are released as CO_2 to the **atmosphere**.
3, 6	The natural gas you are in is burnt and you are released as CO_2 to the **atmosphere**.
4	You stay in the **coal and natural gas** a little longer.

Marine Plants

Roll Die	What happens to you
1, 5	The marine plant you are in is eaten by a **marine animal**.
2, 6	The marine plant you are in is eaten by a **land animal**.
3	The plant you are in died. You are buried, decomposed and, after many years in the rock cycle, become **carbonate rock**.
4	You stay in the **marine plant** a little longer.

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Our Water Supply

Students test the quality of various water supplies, carry out a simple filtration demonstration and investigate the typical water filters used in homes. Students construct and investigate distillation equipment for desalinating water.

Core curriculum skills

Quantitative laboratory testing procedures

Distillation and condensing

Earth science literacy principles

The Earth is a complex system of integrated and interacting subsystems, including the water cycle.

Natural processes affect the environment and people.

Human activities can affect the Earth's natural systems, including groundwater resources, even ones at a distance.

Water supply and consumption is a major issue affecting global society.

Contents

"Water Quality Testing" investigation

"Clean Water for Communities" investigation

"Treating Water in our Homes" investigation

"Desalinating Water Supplies" investigation

Teaching notes

1. Introduce the need for laboratory water testing by showing the students two glasses of water. Unknown to the students, one glass also contains ~15 ml of bleach. Ask them to predict what will happen when a drop of food colouring is added to each glass. Observe the result. Discuss that one glass contained an invisible, non-potable pollutant and that laboratory testing of our drinking water supply is critical.
2. a) Water supplies for the "Water Quality Testing" activity can include:

   Fresh tap water

Tap water that has sat for several hours in an open container
Bottled water
Filtered water
Distilled water
Rainwater
River water
Tap water with garden fertilizer added

b) Use any type of water test kit, including those available for home aquaria, paper-strip tests, data logger probes. Aim to test a selection of nitrate, phosphate, dissolved oxygen, pH, salinity, chlorine and coliform bacteria. School and home pre-packaged combination test kits are readily available commercially.

c) After completing the "Water Quality Testing" investigation, show the students the image of the water cycle (see Resources). Discuss how the path of water through the cycle can add and remove chemicals: e.g., dissolved from rocks, absorbed from the oceans and atmosphere. These chemicals can be either an important source of essential minerals for humans and animals, or a hazardous contaminant.

3. Materials for the "Clean Water for Communities" investigation can be constructed from readily available resources:

   a) Make a filter funnel from an empty pop bottle: cut the bottle in two about halfway up and remove the bottom of the bottle. Invert the top section into the lower section so that the sloped bottle neck creates a funnel.

   b) Create contaminated water by mixing 500 ml soil into 4 L tap water.

   c) Cut the tops off 2-L pop bottles to create the collecting containers.

4. To prepare the solutions needed in "Treating Water in our Homes":

   a) Saturated salt solution: mix 150 g salt with 4 L distilled water. Stir well for 2-3 minutes. Decant into dispensing bottles, ensuring all undissolved salt remains behind.

   b) Prepare contaminated water by mixing into 1 L of distilled water :
   1 g $MgSO_4$ (Epsom salts) as a source of magnesium
   0.5 g potassium nitrate or sodium nitrate
   10 drops of methylene blue to represent organic contaminant.

   Keep sealed until needed.

5. Test the electrical conductivity meter used in “Desalinating Water Supplies” before the investigation. Ensure the combination of power and sensitivity range gives reasonable current readings for salt water and tap water.

Extensions

- Research the effects on health of drinking distilled water, which many bottled waters are, versus tap water.
- Investigate how safe levels are established for chemicals and organics in drinking water.
- Tour a community water treatment plant.
- Research ultra-filtration and reverse osmosis methods of desalination.
- Research Canadian and global access to potable water sources.

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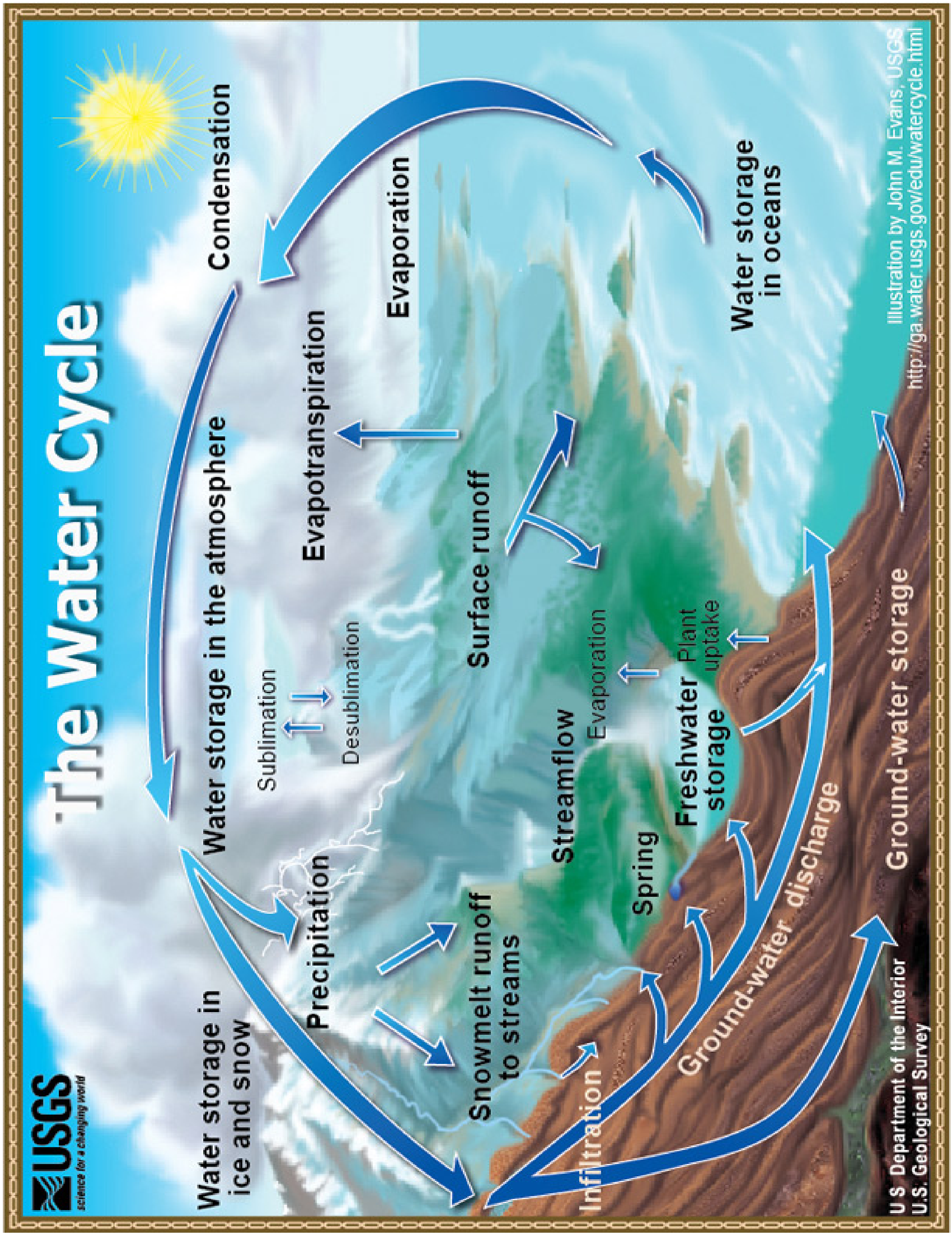
Resources

A water cycle diagram from the United States Geological Survey is on the next page.



The Water Cycle
USGS
science for a changing world
Condensation
Water storage in the atmosphere
Sublimation
Desublimation
Evaporation
Evapotranspiration
Water storage in ice and snow
Precipitation
Snowmelt runoff to streams
Surface runoff
Streamflow
Evaporation
Plant uptake
Freshwater storage
Spring
Infiltration
Ground-water discharge
Ground-water storage
Water storage in oceans
Illustration by John M. Evans, USGS
http://ga.water.usgs.gov/edu/watercycle.html
U.S. Department of the Interior
U.S. Geological Survey

Solutions to student activities

Water Quality Testing

1. Why do you rinse the containers with distilled water between each sample?

   To avoid contamination from previous samples.

2. List any possible reasons why water from different sources contains different chemicals and organisms.

   Pollution, processing methods, the soil and rock through which the water has travelled.

3. What are the positive and negative impacts on humans of drinking tap water? Distilled water? River water?

   Tap water contains essential minerals we need in our bodies. It is inexpensive and tested rigorously for quality.

   Distilled water contains no bacteria contamination, but similarly it has no essential minerals. It is more expensive than tap water, and has no regulated requirement for quality testing.

   River water may/may not contain excess chemicals and bacteria. If it did, it would be unsafe for human consumption. If it did not, it would be a no-cost option for drinking water.

Clean Water for Communities

1. Where does filtration similar to this model occur in nature?

   River beds, stream beds, bottom of ponds and wetlands.

2. What challenges would exist in scaling this filtration method up to a community-sized treatment plant?

   Mixing of coagulants (the alum in the experiment), replenishing filter material, unknown contaminants.

Treating Water in our Homes

1. Which filter removed the organic contaminant?

   Activated charcoal.

2. Which filter removed the magnesium contaminant?

   Water softener.

3. Which filter removed the nitrate contaminant?

   Neither filter. Note: Reverse osmosis is the usual method in homes for removing nitrates.

Desalinating Water Supplies

1. Does the conductivity of the collected water show it to be most like tap water or salt water?

   Tap water.

2. Is there the same total volume of water after heating?

   No. The total volume is less.

3. What is the approximate ratio of potable water to salt water?

   Depends on results.

4. This method is very energy intensive. Describe how you might carry out distillation using solar power.

   Students may consider large- or small-scale operations.

Water Quality Testing

Materials

Water samples
Water quality testing materials
Testing containers, e.g. test tubes
Distilled water

Safety

Clean up any spills immediately.
Follow the safety instructions on each water test kit.

Procedure

1. Copy the results chart below and expand it as necessary to complete the headers for the water samples and water quality test materials available.
2. Rinse your testing containers with distilled water.
3. Working with one water sample at a time, follow the instructions provided on each water quality test.
4. Rinse the testing containers with distilled water between each water sample.
5. Apply the water quality tests to distilled water and record your results.

Observations

Water Sample	Physical description (e.g. colour, odour, particles)	pH		
Distilled water				

Questions

1. Why do you rinse the containers with distilled water between each sample?
2. List any possible reasons why water from different sources contains different chemicals and organisms. Consider both natural and human influences.
3. What are the positive and negative impacts on humans of drinking tap water? Distilled water? River water?

Clean Water for Communities

Materials

500 ml contaminated water sample
2 x 1-L collecting containers
30 ml alum
Large funnel
Coffee filter
250 ml gravel
125 ml coarse sand
125 ml fine sand
Rubber band
10 ml bleach

Safety

Do not drink the water in this investigation.

Clean up any spills immediately.

Procedure

1. Record the appearance and smell of the water.
2. Aerate the water by pouring it back and forth 10 times between the two 1-L collecting containers.
3. Add 30 ml of alum to the water in one of the collecting containers. Slowly stir for 5 minutes. The alum coagulates dirt and other solid particles in the water to form floc.
4. Allow the water to sit for 20 minutes. Gravity pulls the floc particles to the bottom of the container.
5. Meanwhile, construct a filter:

   a) Fold the coffee filter into quarters and attach it to the outside of the funnel neck. Hold it in place with the rubber band.

   b) Clean the filter by pouring tap water through it.

   c) Add 250 ml gravel into the funnel.

   d) Add 125 ml coarse sand on top of the gravel.

   e) Add 125 ml fine sand on top of the coarse sand.
6. Place the filter over the empty collecting container.
7. Without disturbing the floc sediment, pour the water through the filter into the empty collecting container.
8. Record the appearance and smell of the water
9. Add 10 ml bleach to the water as a disinfectant.
10. Record the appearance and smell of the water.

Observations

Water	Appearance	Smell
Initial		
After filtering		
After disinfecting		

Questions

1. Where does filtration similar to this model occur in nature?
2. What challenges would exist in scaling this filtration method up to a community-sized treatment plant?

Adapted from Bow River Waterscape *http://geoscape.nrcan.gc.ca/h2o/bow/index_e.php*

Treating Water in our Homes

You will use activated charcoal and water softener filters to treat a water sample that contains three contaminants:

Organic chemical

Magnesium (Mg_2+, a component of hard water)

Nitrate (NO_3-)

After filtering the water, you will test the treated water to check if the contaminants were removed. You will test a negative and a positive control to show the test results when it is known that contaminants are present or not.

Materials

Safety goggles, gloves

2 x 20 ml syringes (without needles)
Blunt rod
2 regular-size cotton balls
2 large test tubes (25 mm x 220 mm)
Wash bottle with distilled water
Small funnel
10 ml activated charcoal
10 ml water softener resin beads
Wash bottle with saturated salt solution

Part 1: Build the Filters

1. Remove the plungers and caps from the syringes.
2. Using a blunt rod, gently push one cotton ball to the bottom of each syringe. Do not pack tightly.
3. Set each syringe in a large test tube.
4. Saturate each cotton ball with distilled water. Allow excess water to drain into the large test tubes and discard water into liquid waste container.
5. Activated Charcoal Filter:

   a) Using a small funnel, add 10 ml of activated charcoal to one syringe.

   b) Rinse any charcoal dust from the funnel into the syringe with distilled water.

   c) Slowly saturate the charcoal in the filter with distilled water to pre-moisten the filter and improve water flow. Continue until the water runs out clear into the test tube at the bottom.

   d) Dispose of the water from the test tube into the liquid waste container.

   e) Replace the cap and plunger of the syringe and store it upright in the test tube.
6. Water Softener Treatment:

   a) Using the funnel, add 10 ml of water softener resin beads to the other syringe.

   b) Use distilled water to gently rinse any beads from the funnel into the syringe.

c) Slowly saturate the beads in the filter with the saturated salt water solution.

d) Rinse the beads at least 5 more times with the saturated salt-water solution.

e) Rinse the beads with distilled water at least 5 times.

f) Dispose of the water from the test tube into the liquid waste container.

g) Replace the cap and plunger of the syringe and store it upright in the test tube.

Materials

8 small test tubes (16 mm diameter) in a test tube rack
4 rubber stoppers to fit test tubes
25 ml graduated cylinder
Wash bottle with distilled water
Masking tape
40 ml contaminated water sample
Nitrate test (e.g. aquarium test kit)
Liquid soap
Eye dropper
Holder

Part 2: Treating the Water

1. Number the 8 small test tubes 1 to 8 using masking tape and set in a test tube rack.
2. Measure 5 ml distilled water into test tubes 1 and 2. These are the negative controls.
3. Measure 5 ml contaminated water into test tubes 3 and 4. These are the positive controls.
4. Remove the plungers and tip caps from the filter syringes. Empty any liquid that has collected in the test tubes below the filters.
5. Slowly pour 25 ml of contaminated water into the activated charcoal filter. Collect the filtered water in the large test tube.
6. Use the graduated cylinder to measure 5 ml of activated charcoal filtered water into the small test tubes 5 and 6.
7. Rinse out the graduated cylinder with distilled water.
8. Slowly pour 25 ml of contaminated water into the water softener filter. Collect the filtered water in the large test tube.
9. Use the graduated cylinder to measure 5 ml of water softener filtered water into the small test tubes 7 and 8.

Part 3: Testing the Water

1. Organic test:

   a) Hold a sheet of white paper behind the test tube rack.

   b) Compare the colors of the water. Record if the colour has been removed or not.

2. Nitrate test:

   Follow the test kit instructions for the water in test tubes 1, 3, 5, and 7

3. Magnesium Test:

   a) Add 2 drops of liquid soap to test tubes 2, 4, 6 and 8.

   b) Securely place rubber stopper in each test tube.

   c) Gently shake the test tubes.

   d) If the water remains clear and forms bubbles the magnesium has been removed; if the water is cloudy and does not form bubbles the magnesium has not been removed.

Results

Tube	Contents	Colour	Test applied	Test result
1	5 ml distilled water		Nitrate	
2	5 ml distilled water		Magnesium	
3	5 ml contaminated water		Nitrate	
4	5 ml contaminated water		Magnesium	
5	5 ml activated charcoal filtered water		Nitrate	
6	5 ml activated charcoal filtered water		Magnesium	
7	5 ml water softener filtered water		Nitrate	
8	5 ml water softener filtered water		Magnesium	

Questions

1. Which filter removed the organic contaminant?
2. Which filter removed the magnesium contaminant?
3. Which filter removed the nitrate contaminant?

Adapted from: Hydroville http://www.hydroville.org/

Desalinating Water Supplies

Why is salt in water a problem?

Place one freshly cut leafy plant stem into a cup of tap water, and another into a cup of tap water that also contains 15 ml salt. What happens to each of the plants after 15 minutes?

Just like the plants, if we drink water containing excess salt, it makes us ill and prolonged consumption can even cause death.

Salt can get into a water supply from natural salts occurring in the rocks that the water passes through. As well, over-use of an aquifer (groundwater reservoir) to irrigate crops or supply a community with water can increase the concentration of salt.

Many communities globally, including the Prairie regions of Canada currently desalinate some of their water, but they also need to focus on the importance of conserving potable water.

How to measure the salt content of water

Water containing more dissolved salt will conduct electricity better than water with no salt. The size of the electric current can give an estimate of the percentage of total dissolved solids (TDS), which can also be determined more rigorously by evaporation in the laboratory.

Desalinating Water by Distillation

Materials

Ammeter
Two connecting cables with alligator clips
Electrodes (copper strips or paper clips)
9 V battery and holder
Salt water (approximately 15 ml salt in 250 ml water)
Tap water
Long rubber tube
250 ml beaker
500 ml beaker
Aluminum foil
Masking tape
250 ml graduated cylinder
Conical flask with 2-hole rubber bung to fit
Glass tube
Ice
Hot plate
Distilled water

Procedure

1. Assemble the conductivity tester by connecting a series circuit with two electrodes, battery and ammeter.
2. Rinse the electrodes with distilled water and wipe dry. Test the conductivity of a sample of the salt water and a sample of tap water.
3. Assemble the distillation equipment:

   a) Use masking tape to seal a double thickness of aluminum foil over the top of the 250 ml beaker.

   b) Cut a small slit into the aluminum foil and insert 2 cm of one end of the rubber tube. Use masking tape to hold it in place.

   c) Place the 250 ml beaker inside the 500 ml beaker.

   d) Fill the space around the 250 ml beaker with ice.

   e) Join the other end of the rubber tube to one hole of the rubber stopper using a glass tube.

   f) Put 250 ml salt solution in the conical flask.

   g) Insert the rubber stopper in the flask.

   h) Use masking tape to partially cover the unused hole in the stopper. This acts as a pressure release for steam.
4. With the hot plate on medium-low, heat the conical flask. Do not let the flask boil dry. The aim is for most of the steam to pass through the rubber tube. Adjust the masking tape being used as a pressure release to help direct the flow.
5. Stop heating when either the conical flask has only enough water to cover the bottom, or the 250 ml beaker has collected ~2 cm water.
6. Carefully disconnect the aluminum foil and rubber tube from the 250 ml collecting beaker.
7. Test the conductivity of the collected water and the water remaining in the flask. Rinse the electrodes with distilled water and wipe dry before each test.
8. Measure the volume of water left, in the flask and the beaker.

Observations

Water sample	Electrical current (microamperes)	Volume (ml)
Tap water		Not applicable
Salt water		250 ml
Collecting beaker		
Flask after heating		

Questions

1. Does the conductivity of the collected water show it to be most like tap water or salt water?
2. Is there the same total volume of water after heating?
3. What is the approximate ratio of potable water to salt water?
4. This method is very energy intensive. Describe how you might carry out distillation using solar power.

Limestone

Students complete a series of investigations into physical and chemical weathering of limestone (calcium carbonate), both in the laboratory and in the natural environment. They will thermally decompose limestone to create lime. Results are applied to the commercial production of lime from limestone and its use in making concrete.

Core curriculum skills

Identifying acids and bases

Laboratory skills of measurement, filtration, materials handling

Dissolving and precipitation

Thermal decomposition

Writing equations for reactions

Calculating mass relationships in reactions

Earth science literacy principles

The Earth is a complex system of integrated and interacting subsystems, including the rock cycle through which rocks are continually being formed, eroded and changed.

Natural resources are used to create almost everything around us. Anything not developed from a plant or animal resource was mined.

Contents

Teaching notes

1. Plan in advance a location to observe natural stone in the local environment for the "Concrete: Hard as Rock – Or not?" field study. Cemeteries are a good place to see the relative weathering of different rock types.

2. Carry out a risk assessment for each of the investigations considering the students' skills and experience, and the facilities available.

3. For "What is Weathering?" allow 15 minutes for student investigations. Discuss their observations and explain that physical and chemical weathering occurs constantly in the natural environment.

4. In "Chemical Weathering of Limestone":

   a) It is important to note that all rain is naturally acidic because carbon dioxide dissolves in water forming carbonic acid. Acid rain is more acidic because of dissolved pollutants such as sulphur dioxide and nitrogen oxides.

   b) When the students exhale carbon dioxide into the water it becomes acidic. Gradually adding limestone neutralizes the solution because calcium carbonate reacts with the acid. With ground limestone (available in garden centres) the indicator colour change will occur in a few minutes. Limestone chips may take up to an hour to show a colour change.

5. When limestone is heated in "Thermal Decomposition of Limestone," you may see the limestone glowing. This is the origin of the phrase "in the limelight" as it was once used as stage lights. Blowing through a straw into the calcium hydroxide solution (lime water) will turn the solution cloudy as the carbon dioxide in exhaled breath forms a precipitate of calcium carbonate.

6. Show students samples of concrete and cement. Have them read the "Concrete or Cement?" information sheet and visit the virtual tour of cement plant at: http://www.cement.org/basics/images/flashtour.html Emphasize that concrete is a man-made material, but that it cannot be produced without mined natural resources, e.g. limestone and sand.

7. "Quantitative Analysis of Limestone" is intended for senior-level chemistry students due to the reagents involved.

   a) Students should be familiar with laboratory procedures for safe handling of these chemicals.

b) Review the Material Safety Data Sheet and provide necessary safety equipment and instruction.

c) Heating the solution will produce larger calcium oxalate crystals that will be easier to filter; however, this must be carried out in a fume hood due to the corrosive vapours caused.

d) Use a pH meter to precisely control the addition of ammonia prior to precipitating the calcium oxalate. Keeping the pH between 3 and 4.5 maximizes precipitation of calcium oxalate and minimizes precipitation of other metal oxalates.

Extensions

- Identify locations in the local environment and/or find photographs where weathering is apparent.
- Investigate how stalactites and stalagmites are formed in caves when natural limestone dissolved in water precipitates.
- Visit a cement or aggregate operation. These are often located within a short distance of large urban areas to reduce the cost of transporting essential construction materials.
- Research the recycling of construction materials.
- Carry out a comparative study of the calcium content of different limestone samples and evaluate their economic potential as a source of lime..

Solutions to student activities

Chemical Weathering of Limestone

1. What do you add to the water when you blow into it?

   Carbon dioxide.

2. What effect does the limestone have on the solution?

   It changes it from an acid to neutral.

3. How is limestone in the natural environment “attacked” by chemicals?

   By water delivered in rain or by rivers and groundwater.

4. As water trickles through the soil, it picks up more carbon dioxide than it does in the atmosphere. How might this soil water affect limestone?

   Soil water will be more acidic and so will react faster with the limestone, causing more chemical weathering.

5. Where might the property of how limestone reacts with an acid be useful?

   Limestone is valuable in any application where an acid needs to be neutralized, e.g. acidic soils, hazardous waste treatment around landfills or mines, and rural outhouses.

Thermal Decomposition of Limestone

1. What differences are there between the limestone before and after heating?

   The limestone (calcium carbonate) has been decomposed into lime (calcium oxide) and carbon dioxide. Lime is whiter than the unheated limestone, crumbles more easily than limestone and reacts with water.

2. The heated limestone has decomposed to lime. What is the pH of the solution produced when lime reacts with water?

   Alkaline.

3. Name the solution produced.

   Lime water.

4. The formula for limestone (calcium carbonate) is $CaCO_3$ and lime (calcium oxide) is CaO. Write a balanced equation for the reaction when limestone is thermally decomposed.

   $CaCO_3 > CaO + CO_2$

What is Weathering?

Materials

5 pieces of blackboard chalk
Clear plastic bag
2 small cups
Vinegar

Procedure

1. Put 3 pieces of blackboard chalk into a clear plastic bag. Shake. Observe what happens.
2. Put 1 piece of blackboard chalk into a cup of water. Observe what happens.
3. Put 1 piece of blackboard chalk into a cup of vinegar. Observe what happens.

Discussion

Physical weathering occurs when pieces of rock are worn away by impact, abrasion or other physical forces.

Chemical weathering occurs when rock reacts with an agent such as water, and part or all of the rock is removed. The acidity of the water affects the rate of weathering.

Chemical Weathering of Limestone

Materials

Safety goggles
250 ml beaker
Drinking straw
~ 50 ml distilled water
Universal Indicator solution
White paper
10 ml limestone: chips or powder

Safety notes

Wear safety goggles during this experiment. Use one straw per person. Throw the straw away after one person has used it. Only blow through the straw, do not suck up any solution.

Procedure

1. Stand the beakers on a piece of white paper.
2. Pour a 2 cm depth of distilled water into the beaker.
3. Add enough drops of Universal Indicator to produce a strong colour in the water. Record the colour.
4. Blow into the water of both beakers through the straw for one minute each. Record the colour.
5. Carefully drop the limestone into one beaker. Record the colour immediately and again after 15 minutes.

Observations

Note: Universal Indicator colour for acid is yellow, orange or red; neutral is green; and base is blue or purple.

Action Taken	Colour of Water	Acidity
When Universal Indicator added		
When blown into through straw		
Immediately after limestone added		
15 minutes after limestone added		

Questions

1. What do you add to the water when you blow into it?
2. What effect does the limestone have on the solution?
3. How is limestone in the natural environment “attacked” by chemicals?
4. As water trickles through the soil, it picks up more carbon dioxide than it does in the atmosphere. How might this soil water affect limestone?
5. Where might the property of how limestone reacts with an acid be useful?

Thermal Decomposition of Limestone

Materials

Safety goggles
3 pieces of limestone, each about a 1 cm cube.
Dropping pipette
Bunsen burner
Tripod
Gauze
Heatproof mat
Tongs
2 boiling tubes
Universal Indicator solution
Drinking straw

Safety

Wear eye protection.
Use one straw per person. Throw the straw away after one person has used it.
Only blow through the straw, do not suck up any solution.
Do not touch the lime (calcium oxide) that is formed from heating limestone. It will be hot after heating. It is also corrosive.
Calcium oxide will cause burns and is irritating to eyes, skin and the respiratory system.
The reaction of calcium oxide with water is vigorous and exothermic.

Procedure

1. Put on safety goggles and wear them throughout this investigation.
2. Take one piece of limestone. Add a few drops of water and note any reaction.
3. Place two pieces of limestone on a tripod and gauze, and heat with a roaring Bunsen flame for 15 minutes.
4. What changes do you observe, particularly in colour? Optional: darken the room and note what happens when the flame is trained directly on the limestone.
5. Use tongs to place one of the heated pieces onto the heatproof mat. Gently try to crush it with the tongs. Try the same with a piece that has not been heated. Record what you find.
6. Use tongs to place one piece of heated limestone into a test tube. With a dropping pipette add a few drops of water. Record what happens.
7. Now add more water to the test tube until it is about half full. Shake the test tube and pour off the clear liquid: half into one test tube and half into another. Add a few drops of Universal Indicator to one tube and record the pH using a colour chart.
8. Place a straw into the solution in the second tube and blow gently through the straw. Note what happens.

Questions

1. What differences are there between the limestone before and after heating?
2. The heated limestone has decomposed to lime. What is the pH of the solution produced when lime reacts with water?
3. Name the solution produced.
4. The formula for limestone (calcium carbonate) is $CaCO_3$ and lime (calcium oxide) is CaO. Write a balanced equation for the reaction when limestone is thermally decomposed.

Concrete or Cement?

We often use these two words interchangeably to describe what a building or road is made of. In truth, these words have very different meanings.

Cement is a material that can bind other particles together. There are many different types of cement, both natural and man-made. One of the most well known is Portland cement. It is a fine grey powder that is mixed with gravel, sand and water to form **concrete**, which is the most widely used construction material in the world. Portland cement is the crucial ingredient that locks sand and gravel together into concrete. It typically represents 10-15% of a concrete mix, with water being 14-20%, and aggregates (sand, gravel, or rocks) 60-80%.

Portland cement is manufactured by heating a precise mixture of finely ground limestone, clay and sand in a rotating kiln to temperatures reaching 1450 ºC. This results in the production of cement clinker, an intermediate product in the manufacture of cement. The cement clinker is removed from the kiln, cooled, and then finely ground. Take a virtual tour of the production process at the Portland Cement Association website (see web link below).

Portland cement is a precisely controlled chemical combination of calcium, silicon, aluminum, iron and small amounts of other ingredients. Gypsum is added in the final grinding process to regulate the setting time of the concrete. Lime and silica make up about 85% of the mass. Materials used to manufacture Portland cement include limestone, shells and chalk or marl, combined with shale, clay, slate or blast furnace slag, silica sand, and iron ore.

Joseph Aspdin, the English mason who patented the product in 1824, named it Portland cement because it produced a concrete that resembled the colour of natural limestone quarried on the Isle of Portland on the south coast of England.

The manufacture of Portland cement involves about 80 separate and continuous operations, the use of heavy machinery and equipment, and large amounts of heat and energy. The manufacturing process is so precise that the Portland cement must be checked frequently with chemical and physical tests during production. The finished product is also analyzed and tested to ensure that it complies with all specifications.

Sources: Cement Association of Canada **http://www.cement.ca**

Portland Cement Association **http://www.cement.org/basics/images/flashtour.html**

Quantitative Analysis of Lime in Limestone

Materials

Safety goggles
Lab apron
2 x 250 ml beaker
2 filter papers, 1 must be fine-grade
Funnel
50 ml graduated cylinder
Stirring rod
Precision balance scales
Limestone (crushed or powdered)
20 ml 6M hydrochloric acid
25 ml 0.5M ammonium oxalate
5 ml ammonium hydroxide (ammonia)
Methyl orange indicator

Safety

Solutions in this experiment are toxic if ingested and irritant at the concentrations given. If skin contact occurs, wash well with water.
Perform this experiment in a well-ventilated area.

Procedure

1. Collect a specimen of limestone with a mass of approximately 1 g. Record the exact mass in grams to 2 or 3 significant figures.
2. Place the limestone in a beaker.
3. Add 10 ml of 6M hydrochloric acid. Wait until all bubbling stops.

   OPTIONAL: When the acid is added, heat on a hot plate at medium-low heat in a fume hood for 5 minutes. Do not allow to dry.
4. Add 5 ml of additional hydrochloric acid. If bubbling occurs, wait until it stops and continue to add a small amount at a time until no more bubbling occurs.
5. Filter the solution into a clean beaker to remove any insoluble particles.
6. Slowly add 20 ml of 0.5M ammonium oxalate to the solution in the beaker.
7. Add 2 drops of methyl orange indicator to the beaker.
8. Gradually add ammonium hydroxide to the beaker, stirring constantly just until the contents start to turn yellow.
9. Add an additional 5 ml of 0.5M ammonium oxalate.
10. Measure and record the mass of a clean, dry piece of fine-grade filter paper.
11. Filter the solution using the pre-weighed filter paper.
12. Allow the filter paper to dry thoroughly. Either place overnight in a drying oven at 110 C^o or air-dry overnight. Warning: Heating above 200 C^o will decompose the precipitate.
13. Measure and record the mass of the filter paper and precipitate.

Calculations

1. Calculate the mass of the calcium oxalate monohydrate precipitate by subtracting the mass of the filter paper.
2. Calculate the CaO content of your sample by multiplying the mass of the calcium oxalate by 38.39%.
3. Calculate the percentage of CaO in your original sample.

Concrete: Hard as Rock – Or not?

The Earth's rocks are continually being formed, changed and destroyed. Lava solidifying from volcanoes and sediments on the ocean floor create new rocks, while water, wind and ice erode away rocks exposed on the surface.

A rock's resistance to chemical weathering is determined by how susceptible the minerals in the rock are to water or acids. Rocks that are rich in quartz, such as granite, are highly resistant to chemical weathering. At the other end of the scale, marble and limestone, which consist of soluble calcite, are more easily weathered by rain and snow. Quartz sandstones containing feldspar and micas are much less soluble than marble. Fine-grained sandstone consisting almost entirely of quartz is very insoluble and more resistant to chemical weathering.

What about concrete? It is considered chemically to be very durable. For example, it is used for pipes in water treatment plants where it has to withstand both the water and the processing chemicals. Over time, however, acids can chemically weather concrete by dissolving the calcium in the cement and the aggregates which hold it together. Once the cement is weakened, the concrete loses its strength. Concrete structures are also vulnerable when water infiltrates and corrodes the internal metal used to reinforce the concrete. Consider these recent headlines:

"Edmonton woman hurt by falling concrete during thunderstorm" *July 19, 2009*
"Man dies after Montreal parking garage roof collapses" *November 26, 2008*
"Concrete slab falls off Toronto building" *August 14, 2009*
"Fredericton road closed after 10-kilogram chunk of concrete falls" *May 4, 2009*

Source: http://www.cbc.ca/news/

Investigation

1. View a video slide show with a stonemason's commentary about repairs to the cathedral in Worcester, United Kingdom. The images show the effect of weathering on this building, and the steps taken to restore the structure. http://news.bbc.co.uk/2/hi/uk_news/8582504.stm
2. Take a close look at the effects of weathering on local buildings or headstones in a cemetery. Sketch some examples of weathering and record the following details based on your field observations:

   Age of the structure
   Signs of weathering: e.g. rounded corners or edges, pitted surfaces, loss of detail in carvings
   Material (concrete, rock type, physical description)

Rocks and Minerals

Students explore visible spectra produced by prisms and diffraction gratings from white light. They investigate the flame tests of a range of solutions and correlate this to analytical techniques used to determine the chemical composition of rocks.

Core curriculum skills

Chemical formulae

Using flame tests as a characteristic property of elements

Visible spectra using prism and diffraction gratings

Earth science literacy principles

Earth scientists use many tools to observe and study the Earth, including spectrometers and other laboratory instruments.

Natural resources are used to create almost everything around us. Anything not developed from a plant or animal resource was mined.

Contents

"What's in the Rock" investigation

Teaching notes

1. Prepare the testing solutions (see the table below for suggestions). Include at least one instance of two solutions with the same metal, e.g. potassium nitrate and potassium chloride. This allows students to see that it is the cation that determines the flame colour, not the anion. Pre-soak sufficient wood splints in each solution for the whole group.
2. Ask students to describe the colours of a rainbow and if all rainbows look alike. Discuss what they know about how a rainbow is created. Explain that a rainbow is a spectrum where the different colours have been separated. Provide equipment for students to experiment with other sources of spectra: prisms, feathers, diffraction gratings. Ask students to predict if the same colours will appear in every spectrum and if they will always be in the same order. Let students experiment with viewing various light sources and have them share their observations.

3. a) Read the introductory paragraph for "What's in the Rock?" Review the laboratory procedure to be followed, emphasizing the safety procedures for using Bunsen burners and handling chemical solutions.

   b) Allow time for students to complete the flame test investigation. Darkening the room as much as safety allows will improve the visibility of the spectra.

   c) Flame tests can also be carried out with a hand-held propane torch (teacher use only) or a candle. Preparing solutions using methanol will allow a less strong flame to be used. Extreme caution should then be taken since the methanol solutions are highly flammable. Keep the solutions at least 1 m from any naked flame.

   d) After the observations are complete, discuss how the colours seen are determined by the discrete atomic energy levels of each metal. Heating excites the atom's electrons into higher energy levels, and the energy is emitted as light photons when the electrons drop back to lower energy levels. The photon energy is inversely proportional to the wavelength (colour) of the light.

   e) Show students samples of minerals that contain the metallic elements being tested, e.g. muscovite and biotite (potassium), chalcopyrite (copper), calcite (calcium), plagioclase feldspar (sodium), barite (barium), galena (lead), celestine (strontium), tourmaline (lithium) and garnet (magnesium).

Extensions

- Observe elemental spectra lines from gas discharge tubes and correlate the position of the lines to their wavelengths.
- Research how different wavelengths of the electromagnetic spectrum (visible and non-visible) are used in our communities.
- Investigate the applications of spectroscopy in astronomy and what information it can provide about distant stars and planets.

Solutions to student activity

What's in the Rock?

Solution (0.5 M)	Metal	Flame test colour
Potassium nitrate	Potassium	Violet
Potassium chloride	Potassium	Violet
Copper (II) sulphate	Copper	Blue - green
Copper (II) chloride	Copper	Blue - green
Calcium chloride	Calcium	Yellow - red
Sodium chloride	Sodium	Intense yellow
Barium chloride	Barium	Yellow – green
Lead (II) nitrate	Lead	Bright blue
Strontium chloride	Strontium	Scarlet - red
Lithium chloride	Lithium	Magenta – red
Magnesium chloride	Magnesium	Bright white

1. What particles in the solutions are emitting the coloured light?

   Metal atoms

2. What effect does heating the chemicals in a flame have?

   Gives energy to the atoms and excites the electrons.

3. Why do different chemicals emit different colours of light?

   Each chemical has unique energy levels, and it emits light of a wavelength proportional to those energy levels.

4. How could we use the flame test to determine the chemicals in a rock?

   Heat the rock and observe the light emitted. Compare it to known chemicals.

What's in the Rock?

Before we can use the chemicals in the Earth's rocks to produce the materials that make up our everyday products, we need to know the complex mix of molecules and atoms that make up the rock. In most cases, this is done in a laboratory using a spectrometer. A spectrometer is a machine that splits up light into a spectrum. Some spectrometers use a diffraction grating, which bends each wavelength or colour of light at a different angle. The position and strength of each colour in the spectrum is detected by what is called a charge-coupled device (CCD) camera. The specific pattern of coloured lines in the spectrum tells us what elements were in the rock. In this activity, we will find out one cause of these coloured spectra.

Materials

Safety goggles
Bunsen burner
Wood splints
Testing solutions
Diffraction grating
Beaker containing water

Procedure

1. On your observation table add the name and chemical formula for each testing solution to the first column and the metal each contains in the second.
2. Put on safety goggles.
3. Ignite your Bunsen burner. Adjust the air supply so that a blue inner cone is produced.
4. Remove a wood splint from one of the solutions.
5. Pass the splint slowly through the flame at the tip of the blue cone.
6. Observe the colour of the flame.
7. Hold the diffraction grating, by its cardboard frame, close to your eye. Observe the colour of the spectral lines visible as your partner passes the wood splint slowly through the flame again. Rotate the grating to improve the spectrum.
8. Record the colour produced by this solution in the flame test.
9. Quench the wood splint in the beaker of water.
10. Repeat for each of the testing solutions.

Observations

Solution (0.5 M)	Metal	Flame test colour

Questions

1. What particles in the solutions are emitting the coloured light?
2. What effect does heating the chemicals in a flame have?
3. Why do different chemicals emit different colours of light?
4. How could we use a flame test to determine the chemicals in a rock?

Earth's Magnetism

Students investigate the magnetic field patterns of magnets and a model of the Earth. They observe the effects of induced electrical current from a moving coil and magnet arrangement, and establish the magnetic field generated by an electric current. Students map the positions of the Earth's North Magnetic Pole and South Magnetic Pole over the last 100 years.

Core curriculum skills

Magnetic field of a dipole magnet and current carrying coil

Induced electromotive force (EMF) in a conductor

Graphing in polar coordinates

Earth science literacy principles

The Earth is a complex system of integrated and interacting subsystems in both its internal structure and in its external environment, the solar system.

Earth is a dynamic entity that changes over time.

Contents

Teaching notes

1. Construct a model Earth for student investigation (see directions below).
2. Construct wire coils from 20-gauge magnet wire wound about 100 times in a 5 cm diameter and held in place with duct tape.
3. If preferred, construct the magnetic field detectors for students' use rather than have them construct their own.
4. Print maps (see Resources) for students to use in "The Wandering Poles" assignment.

5. Have students investigate the basic magnetic field patterns and apply this to the Earth in "Looking at Magnetic Fields." To supplement the model Earth, view images of the Earth's magnetosphere at NASA's "Mission to Geospace" website: http://pwg.gsfc.nasa.gov/istp/outreach/theretohere.html

Extensions

- Research navigation compasses and exploration magnetometers.
- Investigate the magnetic fields of other planets and the Sun.
- Study NASA materials (see link above) concerning solar influence on the magnetosphere.

How to construct a model Earth

The model is a dipole magnet inside a sphere.

1. You can use either a large bar magnet or two disc magnets on either end of ferromagnetic rod, e.g. a steel bar. Make sure both disc magnets are oriented the same way: they should attract each other if the ferromagnetic rod is removed.
2. Insert the magnet into a sphere, representing Earth, using one of the following options:
    - Cut a rubber ball in half, hollow out space for the magnet and stick the ball back together.
    - Cut a tennis ball in half, firmly wedge magnet into centre and stick the ball back together.
    - Shape playdough into a sphere around the magnet.
    - Place magnet inside a clear, fillable plastic sphere such as those used for making customized Christmas tree decorations.
3. Keep note of the magnet's orientation. The magnet's south pole should be located slightly to the west of where you will site the geographic North Pole.
4. Mark the following on the planet surface:
    - Equator
    - Prime meridian (0^{o} longitude)
    - Lines of longitude at 90^{o} east, 180^{o}, 90^{o} west
    - Geographic North Pole and South Pole

    There should be 8 equal sectors around the surface.

Earth's Magnetism

Solutions to student activities

What Creates the Earth's Magnetic Field?

1. Why don't the Earth's geographic and magnetic poles line up?

   The geographic poles are determined as the ends of the axis of rotation and so are fixed in space. The magnetic poles are controlled by dynamic, changing currents in the Earth's liquid outer core and are, therefore, constantly moving.

2. If a planet has magnetic field, what can we infer?

   Assuming that other planets display similar physical properties as Earth, the presence of a magnetic field implies the existence of liquid currents that produce the magnetic field. This presents the possibility of there also being an active tectonic system, driven by convection.

The Wandering Poles

1. Plot the motion of the North Magnetic Pole and the South Magnetic Pole on maps of the region.
2. Using the map scale, measure the distance moved between each point.
3. Calculate the speed each pole has moved during each time period.

   Distances and speed will depend on map resolution used; these are approximate.

North Pole

Year	Longitude	Latitude	Distance (km)	Speed (km/year)
1831	96.5	70.1	-	-
1904	96.2	70.5	50	0.7
1948	101.1	73.8	350	8
1962	100.8	75.0	250	17
1973	101.3	76.1	150	13
1984	102.1	77.2	150	13
1994	104	78.5	150	15
2001	110.8	81.3	300	42

Source Geological Survey of Canada

South Pole

Year	Latitude (°N)	Longitude (°W)	Distance moved (km)	Speed (km/yr)
1903	-72.9	156.4	-	-
1909	-71.6	152.0	250	41
1912	-71.17	150.8	100	33
1931	-70.3	149.04	250	13
1952	-68.1	143.0	350	16
1962	-67.5	140.0	350	35
1986	-65.3	140.0	500	21

Source: Woods Hole Oceanographic Institution

4. Predict locations for each pole in 2020, based on your observations.

   Answers will vary and should be justified by map results.

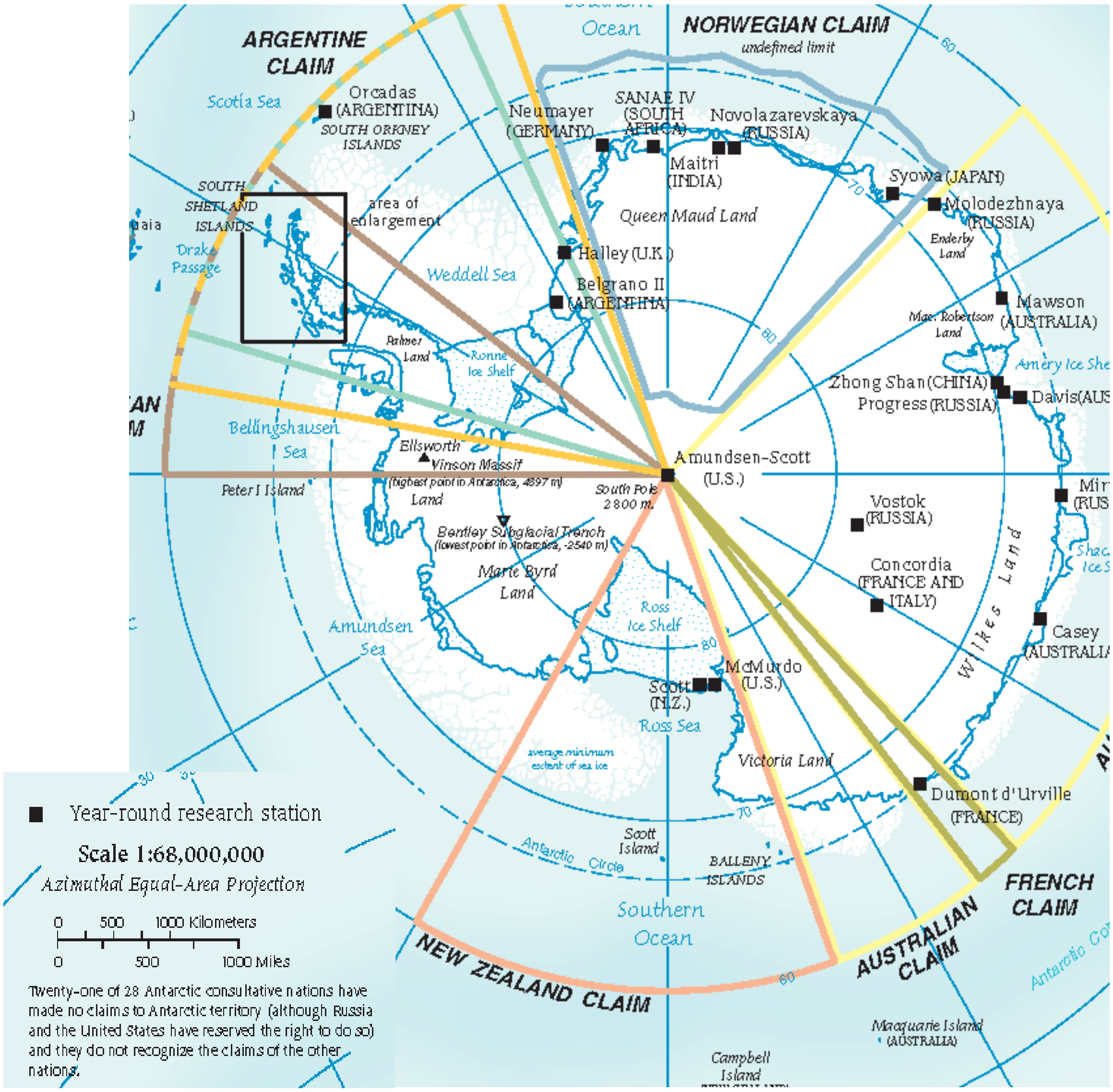
Resources

Map Source: The World Fact Book, Central Intelligence Agency

https://www.cia.gov/library/publications/the-world-factbook/

Map of Arctic

Map of Antarctic



Build a Magnetic Field Detector

Materials

Drinking straw
2 steel pins
Tape
Thread
Bar magnet
Optional: compass (if magnet not labelled)

Construction

1. Stick two pins, tip to tip, on the tape so that the heads protrude off edges of the tape.
2. Stroke the pins gently with the bar magnet
3. Lay thread over the tape at 90^{o} to the pins so that end overlaps the pins. Close up the tape to hold the thread and pins in place.
4. Feed the thread through the straw so that the pins on the tape hang freely below.
5. Tape the thread to the top of straw, so that the straw becomes the handle for your magnetic field detector.
6. If the magnet is not labelled, identify its north and south poles by using a compass.
7. Bring your magnetic field detector close to the north pole of the magnet. One of the pins should rotate to point to the magnet. Label this edge of tape "north".
8. Bring it close to the south pole of the magnet; the other pin should point to magnet. Label this pin "south."

Discussion

This is a simple, but mechanically similar, version of the magnetometers used to explore other planets. On a spaceship, a magnetometer must be mounted outside on a long boom, so that it is not influenced by any of the electric or magnetic systems on board.

Looking at Magnetic Fields

Materials

Magnetic field detector

Selection of magnets: bar, disk, donut shapes

Optional: iron filings, plastic bag, tray, white paper

Model Earth

Procedure

Part 1: Magnets

1. Sketch a diagram of each magnet.
2. Use your magnetic field detector to locate the north and south poles, and label them on your diagram.
3. Place the detector at many different locations around the magnet. On your diagram sketch lines showing how the detector is aligned at each point.

   Optional: Seal one magnet in plastic bag. Place the bag flat on the tray and cover it with a sheet of paper. Sprinkle the paper with iron filings. Sketch the patterns produced on your diagram. When done, open the bag carefully over the tray. Remove the magnet and let the iron filings drop on to the tray.
4. Repeat for each of the different magnets available.

Part 2: Model Earth

1. Sketch a diagram of the model Earth, including all the labels on it.
2. Use the magnetic field detector to locate the North Magnetic Pole and the South Magnetic Pole, and label them on your diagram.
3. Place the detector at many different locations around the model Earth. On your diagram, sketch lines to show how the detector is aligned at each point.
4. Which of the different magnets that you investigated creates a magnetic field most like that of the model Earth?

What Creates the Earth's Magnetic Field?

Materials

1 wire coil (approximately 100 turns, diameter 5 cm)
Strong magnet
Multimeter (200mV scale) and 2 leads with alligator clips
Magnetic field detector
Battery and holder

Procedure

Part 1 – Dynamo

1. Connect the ends of the wire coil to the multimeter.
2. Move coil over one pole of the magnet. Observe the multimeter carefully.
3. Move the coil over the other pole of the magnet and observe the multimeter.
4. Move the magnet over, into and through the coil, and observe the multimeter.

Part 2 – Motor

5. Connect the coil to the battery.
6. Use the magnetic field detector to investigate the area around and within the coil.
7. Disconnect the battery when done.
8. Sketch a diagram of the magnetic field.
9. Reverse the connections on the battery, and repeat steps 6, 7 and 8.

Discussion

Part 1 of this experiment is a dynamo, which converts kinetic energy into electrical energy as a conductor moves relative to a magnetic field. If the direction of motion is reversed, the direction (polarity) of current also reverses. The size of the current is controlled by the speed of motion.

Most dynamos can also work as an electric motor: if a current is provided to a conductor in a magnetic field, a force is created that can turn either the conductor or the magnet.

The Earth's outer core consists of molten iron and is, therefore, an electrical conductor. The molten iron is moving due to convection currents and the Earth's rotation. The outer core, therefore, acts as a dynamo: as the liquid moves within the existing magnetic field, an electrical current is generated in the molten iron. These electric currents in the molten iron generate their own magnetic field. The dynamo effect in the outer core becomes self-sustaining.

Questions

1. Why don't the Earth's geographic and magnetic poles line up?
2. If a planet has magnetic field, what can we infer?

The Wandering Poles

Materials

Ruler
Maps of arctic and Antarctic regions

Data

North Pole

Year	Latitude (°N)	Longitude (°W)	Distance (km)	Speed (km/year)
1831	96.5	70.1		
1904	96.2	70.5		
1948	101.1	73.8		
1962	100.8	75.0		
1973	101.3	76.1		
1984	102.1	77.2		
1994	104	78.5		
2001	110.8	81.3		

Source Geological Survey of Canada

South Pole

Year	Latitude (°N)	Longitude (°W)	Distance moved (km)	Speed (km/yr)
1903	-72.9	156.4		
1909	-71.6	152.0		
1912	-71.17	150.8		
1931	-70.3	149.04		
1952	-68.1	143.0		
1962	-67.5	140.0		
1986	-65.3	140.0		

Source: Woods Hole Oceanographic Institution

1. Plot the motion of the North Magnetic Pole and the South Magnetic Pole on maps of the region.
2. Using the map scale, measure the distance moved between each point.
3. Calculate the speed each pole has moved during each time period.
4. Predict locations for each pole in 2020, based on your observations.

River Flow

Students graph and look for correlations between river flow and precipitation data. They measure stream velocity and relate this to the ability to move sediment and river erosion. Statistical analysis is applied to interpret their observations. Students calculate the percentage of sediment in a river sample and calculate how carrying sediment affects the water's kinetic energy.

Core curriculum skills

Graphing data

Statistical analysis: mean, range, standard deviation

Calculating and manipulating percentages

Calculating velocity and kinetic energy

Earth science literacy principles

Natural processes are continuously changing the landscape around us.

The Earth is a complex system of integrated and interacting subsystems, including the water cycle.

Studying natural processes can provide valuable information to mitigate any harmful effects.

Contents

"Cyclical River Flow" graphing assignment

"Measuring Stream Velocity" investigation

"Suspended Sediment and Kinetic Energy in a River" investigation

Teaching notes

1. Data for graphing in the "Cyclical River Flow" assignment is included as a paper copy and digital file.
2. The "Measuring Stream Velocity" investigation can be performed in the field (preferred) or in the classroom using a model stream (e.g. a sand table, sections of eavestrough, piping, etc.). Before taking students into the field, you should undertake a risk assessment of the

proposed study site and implement suitable safety procedures for working around water. Students may use technology to calculate the standard deviation required in their results.

3. For "Suspended Sediment and Kinetic Energy in a River" students will need access to a river or stream to measure the actual velocity and sediment content of the water. Depending on the students' experimental skills, additional prompts or suggestions can be given to help them design their investigation.

Extensions

- Download Environment Canada data to carry out flow and climate correlations for other locations: river flow from the Water Survey of Canada at: http://www.wsc.ec.gc.ca and climate data from the National Climate Archive: http://climate.weatheroffice.gc.ca/
- Investigate the effect on data variability of using longer or shorter distances along the river, or other identified influences.
- Investigate the velocity and depth profile across the river.
- Research the damage from sediment flows (this can link to the Landslides activity).

Solutions to student activities

Cyclical River Flow

1. Access the rainfall and river flow data for Thompson, Manitoba.
2. Using a spreadsheet program, plot the two data sets on the same graph.
3. Compare the two data sets. What correlations can you see?

   Flow peaks after extreme rain fall, stays mostly constant when no rain fall.
4. Why is there a lag between rainfall and increased discharge?

   Rain does not only fall directly into the river, but also on the land within the entire drainage basin. Rain that falls on land will soak in and eventually pass through the water table into the river. The peak takes some time to reach the river.

5. Are there any peaks in river flow not related to rainfall? Why?

   There is a dramatic increase in river flow in the spring with no associated rainfall. This will be related to the spring thaw adding meltwater to the river.

6. Based on the flow data, during what times of year is there a risk of flooding on this river?

   Spring.

Measuring Stream Velocity

1. What factors introduce variability to this experiment?

   Measurement errors include length and time.

   Releasing the floating object in a different position will likely result in different times.

   Variation in current velocity and turbulence may cause the object to float at a different speed or on a different path.

   If a different object is used each time (such as 5 different pine cones), they may have different hydrodynamic properties.

   An object that gets waterlogged may take a different path if it is no longer sitting on the surface.

2. Would longer measurement distances reduce variability of results?

   Generally longer distances should reduce some of the human error introduced.

3. At which part of the bend is the water moving fastest?

   Water moves fastest on the outside of the bend.

4. Optional: Which is deeper water, the inside or outside of the bend?

   The deeper part of the stream is on the outside of the curve. This coincides with faster water velocities.

5. Where on the river could you go to get faster and slower velocities?

   On bends, the outside water will move faster and the inside water will move slower.

   Where the stream width narrows, the water will flow faster.

   On steeper slopes, the water will move faster.

6. Look at Hjulstrom's diagram, which was developed by the Swedish scientist, Filip Hjulstrom (1902-1982), and

relates stream velocity and sediment size. It is a positional graph where three fields classify the behaviour of the sediment particles as deposition, transportation or erosion. Both axes are a logarithmic scale, meaning each number is 10 times larger than the previous.

Determine what sediment size can be moved by the current you measured.

Depends on observations.

7. At what velocity would the water move pebbles with a 1 cm diameter?

   The pebble would be eroded out of the riverbed once the velocity exceeded 20 cm/s, then continued to be moved as long as the velocity did not drop below 7 cm/s.

8. When do you think you would get those conditions on the river?

   Possibly during heavy rains, spring thaw and flood conditions.

9. Why does the water velocity needed to erode rocks increase as the particle size decreases below 0.1 mm?

   Small, very fine particles adhere together with greater force than larger particles. Imagine how sticky clay and mud is as compared to sand.

10. Based on your observations and Hjulstrom's diagram, where do you think erosion is most likely to occur in the river?

    The inside curve of a riverbank experiences sedimentation due to slower velocities, while the outside curve of a riverbank is actively eroded by the faster velocities.

11. Predict what will happen to the path of the river in the future.

    The curve will grow bigger in a direction perpendicular to the general downslope path of the stream. This looping pattern is known as a meander. Eventually the meander will become too big and will be cut off and abandoned as the water finds a more direct path (usually during a flood). Abandoned meanders often remain filled with water and these are called oxbow lakes.

Suspended Sediment and Kinetic Energy in a River

Design and perform an investigation to determine whether the amount of rock material carried in the river water appreciably impacts the kinetic energy.

Students will need to measure the stream velocity as in the previous investigation. They will need to take a water sample of known volume and measure the mass. Consideration needs to be given as to how to take a representative sample, and the sample must be taken in the same region where the velocity is measured.

1. What percentage of the river sample's mass is sediment?

   If the percentage of sediment by mass is x, the percentage of water by mass is 1-x.

   Density = mass/volume

   For a standard volume of 1 m3

   *Density river sample = (density of sediment * x) + (density of water * (1-x))*

   Rearrange to find the percentage x of sediment by mass:

   *Density river sample = (density of sediment * x) + density of water - (density of water * x)*

   Density river sample – density of water = x (density of sediment – density of water)

   x = (density of river sample – density of water) / (density of sediment – density of water)

   For example, if the sample density is 1050 kg / m3, density of typical river sediment is 2650 kg/m3 and the density of water is 1000 kg/m3:

   Percentage of sediment by mass = (1050 – 1000) / (2650 – 1000) = 0.03 = 3%

2. What percentage increase does this have on the water's kinetic energy?

   Since $E_k = (1/2)\,mv^2$ the kinetic energy is directly proportional to the mass.

   The percentage increase in river sample mass = (1050 – 1000) / 1000 = 0.05 = 5%

   Therefore 3% sediment content by mass results in a 5% increase in kinetic energy.

   In most cases, the experiment will yield negligible impact on kinetic energy.

3. Can you think of some situations where a sediment/water mix will have a significantly higher kinetic energy assuming the same velocity? Would the fluid in these situations behave differently?

   Debris flows, mudslides and volcanic lahars would all have a high kinetic energy relative to our experiment *because they have high rock content. These fluids would have higher viscosity.*

Example: a debris flow with 40% sediment

*Density river sample = (density of sediment * x) + (density of water * (1-x))*

*= (2650 * 0.4) + (1000(1-0.4))*

= 1660 kg/m^3

A 1-litre volume will have a mass equal to 1.66 times the mass of pure water, an increase of 66%. The kinetic energy will also increase by 66%. These types of sediment and water mixes can be extremely destructive if this energy is transferred to objects in their path.

Cyclical River Flow

Monitoring stations, located throughout Canada, record measurements of the natural environment. This includes climate data such as temperature and precipitation, and river data such as water level and flow volume. Some of these stations transmit their data in real-time, and this permits the rapid production of our daily weather reports and immediate responses to potential hazards like floods. All of the data is archived and kept for reference and research. By studying the patterns over time, we can prepare and remediate against catastrophic effects, or respond to changes observed.

Rivers are one part of an immense and continuous Earth process called the water cycle. Water in rivers flows downhill to the oceans, evaporates into the air, and is taken up by plants and trees. Once in the air, the water vapour condenses into clouds, which in turn create precipitation that adds water back into the ground. Groundwater seeps into river channels and the cycle continues. All the elements of the system are interconnected and influence each other.

Looking at Thompson, Manitoba

1. Access the rainfall and river flow data for Thompson, Manitoba from the National Climate Archive (http://climate.weatheroffice.gc.ca/) and the Water Survey of Canada (http://www.wsc.ec.gc.ca).
2. Using a spreadsheet program, plot the two data sets on the same graph.
3. Compare the two data sets. What correlations can you see?
4. Why is there a lag between rainfall and increased discharge?
5. Are there any peaks in river flow not related to rainfall? Why?
6. Based on the flow data, during what times of year is there a risk of flooding on this river?

Recorded Data

Date/Time	rain	flow
01/01/2008	0	1050
02/01/2008	0	1050
03/01/2008	0	1040
04/01/2008	0	1040
05/01/2008	0	1040
06/01/2008	0.4	1040
07/01/2008	0	1040
08/01/2008	0	1040
09/01/2008	0	1040
10/01/2008	0	1040
11/01/2008	0	1040
12/01/2008	0	1040
13/01/2008	0	1040
14/01/2008	0	1030
15/01/2008	0	1030
16/01/2008	0	1030
17/01/2008	0	1030
18/01/2008	0	1030
19/01/2008	0	1030
20/01/2008	0	1030
21/01/2008	0	1030
22/01/2008	0	1030
23/01/2008	0	1030
24/01/2008	0	1020
25/01/2008	0	1020
26/01/2008	0	1020

Date/Time	rain	flow
27/01/2008	0	1020
28/01/2008	0	1020
29/01/2008	0	1020
30/01/2008	0	1020
31/01/2008	0	1020
01/02/2008	0	1020
02/02/2008	0	1020
03/02/2008	0	1010
04/02/2008	0	1010
05/02/2008	0	1010
06/02/2008	0	1010
07/02/2008	0	1010
08/02/2008	0	1010
09/02/2008	0	1010
10/02/2008	0	1010
11/02/2008	0	1010
12/02/2008	0	1010
13/02/2008	0	1000
14/02/2008	0	1000
15/02/2008	0	1000
16/02/2008	0	1000
17/02/2008	0	1000
18/02/2008	0	999
19/02/2008	0	998
20/02/2008	0	997
21/02/2008	0	996

Date/Time	rain	flow
22/02/2008	0	995
23/02/2008	0	994
24/02/2008	0	994
25/02/2008	0	993
26/02/2008	0	993
27/02/2008	0	993
28/02/2008	0	992
29/02/2008	0	992
01/03/2008	0	991
02/03/2008	0	991
03/03/2008	0	990
04/03/2008	0	990
05/03/2008	0	990
06/03/2008	0	989
07/03/2008	0	989
08/03/2008	0	988
09/03/2008	0	988
10/03/2008	0	988
11/03/2008	0	987
12/03/2008	2.8	987
13/03/2008	0	987
14/03/2008	0	987
15/03/2008	0	987
16/03/2008	0	987
17/03/2008	0	987
18/03/2008	0	987

Date/Time	rain	flow
19/03/2008	0	987
20/03/2008	0	987
21/03/2008	0	988
22/03/2008	0	988
23/03/2008	0	988
24/03/2008	0	987
25/03/2008	0	987
26/03/2008	0	987
27/03/2008	0	987
28/03/2008	0	988
29/03/2008	0	987
30/03/2008	0	987
31/03/2008	0	987
01/04/2008	0	987
02/04/2008	0	987
03/04/2008	0	987
04/04/2008	0	987
05/04/2008	0	987
06/04/2008	0	987
07/04/2008	0	987
08/04/2008	0	987
09/04/2008	0	992
10/04/2008	0	1000
11/04/2008	0	1010
12/04/2008	0	1010
13/04/2008	0	1020
14/04/2008	0	1030
15/04/2008	0	1040
16/04/2008	0	1060

Date/Time	rain	flow
17/04/2008	0	1080
18/04/2008	0	1100
19/04/2008	0	1120
20/04/2008	0	1140
21/04/2008	0.2	1160
22/04/2008	0.2	1180
23/04/2008	0	1200
24/04/2008	0	1290
25/04/2008	0	1350
26/04/2008	0	1370
27/04/2008	0	1360
28/04/2008	0	1370
29/04/2008	0	1360
30/04/2008	0	1340
01/05/2008	0	1320
02/05/2008	0	1300
03/05/2008	0	1270
04/05/2008	0	1250
05/05/2008	0	1230
06/05/2008	0	1220
07/05/2008	0	1190
08/05/2008	0	1180
09/05/2008	0	1170
10/05/2008	0	1160
11/05/2008	0	1150
12/05/2008	0	1140
13/05/2008	3.8	1130
14/05/2008	0.2	1130
15/05/2008	0	1130

Date/Time	rain	flow
16/05/2008	6.4	1140
17/05/2008	0	1140
18/05/2008	0	1160
19/05/2008	0	1160
20/05/2008	0	1170
21/05/2008	0	1170
22/05/2008	0	1170
23/05/2008	0	1170
24/05/2008	0	1170
25/05/2008	0	1170
26/05/2008	0	1170
27/05/2008	0	1160
28/05/2008	0	1160
29/05/2008	0	1160
30/05/2008	10	1160
31/05/2008	0	1160
01/06/2008	0	1150
02/06/2008	0	1150
03/06/2008	0	1140
04/06/2008	0.4	1150
05/06/2008	0	1140
06/06/2008	0	1140
07/06/2008	0	1140
08/06/2008	0	1140
09/06/2008	0	1130
10/06/2008	0	1120
11/06/2008	0	1110
12/06/2008	4.2	1110
13/06/2008	1	1110

Date/Time	rain	flow
14/06/2008	0.4	1110
15/06/2008	0	1100
16/06/2008	0	1100
17/06/2008	0	1090
18/06/2008	0	1080
19/06/2008	0	1070
20/06/2008	0	1060
21/06/2008	0	1050
22/06/2008	2	1040
23/06/2008	5.6	1020
24/06/2008	27.6	1010
25/06/2008	0	994
26/06/2008	4.1	974
27/06/2008	0	956
28/06/2008	0	936
29/06/2008	0	913
30/06/2008	1.2	893
01/07/2008	0	881
02/07/2008	0	862
03/07/2008	1.6	849
04/07/2008	0.6	839
05/07/2008	65.8	846
06/07/2008	0.4	852
07/07/2008	0.6	854
08/07/2008	1.8	855
09/07/2008	1.6	852
10/07/2008	0.2	846
11/07/2008	18	844
12/07/2008	18.5	861

Date/Time	rain	flow
13/07/2008	3.2	864
14/07/2008	3	869
15/07/2008	1.2	872
16/07/2008	3.4	873
17/07/2008	0.6	874
18/07/2008	0	873
19/07/2008	0	871
20/07/2008	0	866
21/07/2008	0	856
22/07/2008	0	840
23/07/2008	2.2	828
24/07/2008	3.2	815
25/07/2008	3.2	802
26/07/2008	0	789
27/07/2008	0	777
28/07/2008	18.4	768
29/07/2008	0.4	761
30/07/2008	0	750
31/07/2008	2.8	743
01/08/2008	0	736
02/08/2008	11.6	731
03/08/2008	1.2	723
04/08/2008	0.8	716
05/08/2008	2.6	713
06/08/2008	2.8	711
07/08/2008	0	708
08/08/2008	0	706
09/08/2008	0	703
10/08/2008	0	699

Date/Time	rain	flow
11/08/2008	0	695
12/08/2008	0	691
13/08/2008	0	685
14/08/2008	0	679
15/08/2008	0	671
16/08/2008	32.4	667
17/08/2008	0	665
18/08/2008	0	657
19/08/2008	0	650
20/08/2008	0	649
21/08/2008	28.7	652
22/08/2008	7.4	664
23/08/2008	2	663
24/08/2008	0	662
25/08/2008	0	663
26/08/2008	7.2	668
27/08/2008	11.2	670
28/08/2008	0	681
29/08/2008	0	693
30/08/2008	0.8	706
31/08/2008	0	719
01/09/2008	0	735
02/09/2008	0	752
03/09/2008	0.8	770
04/09/2008	0.6	790
05/09/2008	4.8	813
06/09/2008	2.6	832
07/09/2008	0.6	848
08/09/2008	0	862

Date/Time	rain	flow
09/09/2008	0	877
10/09/2008	0	892
11/09/2008	0	903
12/09/2008	3	914
13/09/2008	5	931
14/09/2008	0	939
15/09/2008	4.8	954
16/09/2008	1.8	964
17/09/2008	0	969
18/09/2008	0.6	978
19/09/2008	0.8	982
20/09/2008	0	986
21/09/2008	0	994
22/09/2008	0	1000
23/09/2008	7.8	1010
24/09/2008	0.8	1010
25/09/2008	0	1010
26/09/2008	0	1010
27/09/2008	0	1010
28/09/2008	18	1030
29/09/2008	0.4	1030
30/09/2008	0.2	1040
01/10/2008	0.4	1040
02/10/2008	0	1050
03/10/2008	0	1050
04/10/2008	0	1050
05/10/2008	0	1050
06/10/2008	7.2	1060
07/10/2008	2	1060

Date/Time	rain	flow
08/10/2008	3.2	1060
09/10/2008	0.2	1060
10/10/2008	0	1060
11/10/2008	0	1060
12/10/2008	0.2	1060
13/10/2008	0	1060
14/10/2008	0.2	1060
15/10/2008	0	1060
16/10/2008	0	1060
17/10/2008	0	1060
18/10/2008	0	1060
19/10/2008	0	1060
20/10/2008	0	1060
21/10/2008	1.2	1060
22/10/2008	1.2	1050
23/10/2008	0	1050
24/10/2008	0.2	1050
25/10/2008	0	1050
26/10/2008	0	1040
27/10/2008	0	1040
28/10/2008	0	1050
29/10/2008	0	1050
30/10/2008	0	1040
31/10/2008	0	1040
01/11/2008	0.4	1040
02/11/2008	0	1040
03/11/2008	0.6	1040
04/11/2008	0.4	1050
05/11/2008	0	1050

Date/Time	rain	flow
06/11/2008	0	1050
07/11/2008	0	1050
08/11/2008	0	1040
09/11/2008	0	1040
10/11/2008	0	1030
11/11/2008	0	1030
12/11/2008	0	1030
13/11/2008	0	1030
14/11/2008	0	1020
15/11/2008	0	1030
16/11/2008	0	1030
17/11/2008	0	1030
18/11/2008	0	1030
19/11/2008	0	1030
20/11/2008	0	1030
21/11/2008	0	1030
22/11/2008	0	1030
23/11/2008	0	1030
24/11/2008	0	1030
25/11/2008	0	1030
26/11/2008	0	1030
27/11/2008	0	1020
28/11/2008	0	1020
29/11/2008	0	1020
30/11/2008	0	1020
01/12/2008	0	1020
02/12/2008	0	1020
03/12/2008	0	1020
04/12/2008	0	1020

Date/Time	rain	flow
05/12/2008	0	1020
06/12/2008	0	1020
07/12/2008	0	1020
08/12/2008	0	1020
09/12/2008	0	1020
10/12/2008	0	1020
11/12/2008	0	1020
12/12/2008	0	1020
13/12/2008	0	1020
14/12/2008	0	1020
15/12/2008	0	1020
16/12/2008	0	1020
17/12/2008	0	1020
18/12/2008	0	1020
19/12/2008	0	1020
20/12/2008	0	1020
21/12/2008	0	1020
22/12/2008	0	1020
23/12/2008	0	1020
24/12/2008	0	1010
25/12/2008	0	1010
26/12/2008	0	1010
27/12/2008	0	1010
28/12/2008	0	1010
29/12/2008	0	1010
30/12/2008	0	1010
31/12/2008	0	1010

Measuring Stream Velocity

Materials

Small buoyant object (rubber duck, pine cone, etc.)
Tape measure
Stopwatch
Metre stick (optional)
Access to a natural river or a model stream

Safety

When working around a body of water:
Never work alone. Use a buddy system and always know where your buddy is. Preferred working group size is 3 or more.
Non-swimmers should wear a personal flotation device at all times.
Take extreme care on banks.
Do not enter the water unless specifically instructed to do so.

Procedure

1. Mark out a straight stretch of a river where your buoyant object can float freely.
2. Place one person at Point A (the start, upstream), and one at Point B (the finish, downstream).
3. Measure the distance from Point A to Point B.
4. Drop the object into the water at Point A, as close to the middle of the river as possible.
5. Time how long it takes for the object to move from Point A to Point B.
6. Repeat the test 5 times.
7. Find a bend in a river where your buoyant object can float freely.
8. Repeat steps 2 to 6 dropping the object on the inside of the bend.
9. Repeat steps 2 to 6 dropping the object on the outside of the bend.
10. If it can be done safely, measure the depth of the water across the river channel at the bend.

Observations

	Distance (m)	Time 1 (s)	Time 2 (s)	Time 3 (s)	Time 4 (s)	Time 5 (s)	Mean Time (s)	Mean Velocity (m/s)	Velocity Range	Velocity Standard Deviation
Straight										
Inside bend										
Outside bend										

Notes:

Mean = sum of all data / total number of data

Velocity = distance / time

Range = maximum - minimum

Standard deviation =

$$\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(X_i - x\right)^2}$$

where n = number of sample points, Xi is each value, x is the mean of the data set

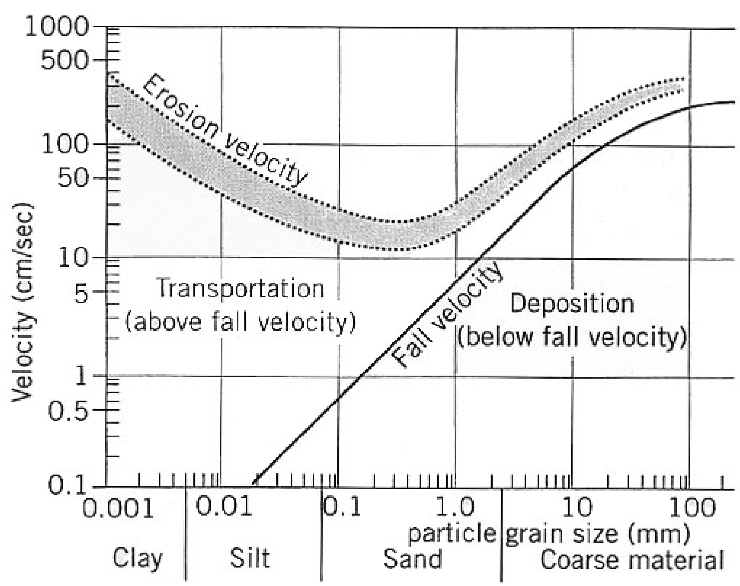
Questions

1. What factors introduce variability to this experiment?
2. Would longer measurement distances reduce variability of results?
3. At which part of the bend is the water moving fastest?
4. Optional: which is deeper water, the inside or outside of the bend?
5. Where on the river could you go to get faster and slower velocities?

Look at Hjulstrom's diagram (below), which was developed by the Swedish scientist, Filip Hjulstrom (1902-1982), and relates stream velocity and sediment size. It is a positional graph where three fields classify the behaviour of the sediment particles as deposition, transportation or erosion. Both axes are a logarithmic scale, meaning each number is 10 times larger than the previous.

6. Determine what sediment size can be moved by the current you measured.
7. At what velocity would water move pebbles with a 1 cm diameter?
8. When do you think you would get those conditions on the river?
9. Why does the water velocity needed to erode rocks increase as the particle size decreases below 0.1 mm?
10. Based on your observations and Hjulstrom's diagram, where do you think erosion is most likely to occur in the river?
11. Predict what will happen to the path of the river in the future.

Hjulstrom`s Diagram



Suspended Sediment and Kinetic Energy in a River

Glacial melting in the summer increases water volume later in the day during the summer months in British Columbia's Kicking Horse River. This increase in glacial meltwater is marked by the river's water turning a milky colour, which is due to the glacial flour (very fine grains of rock created by glacial erosion) being added to the river by the melting glaciers. Seasonal or storm-related increases in water flow might also demonstrate an increase in the amount of sediment carried in the water.

Materials

Accurate scale
Access to a natural river
1-litre wide-mouthed container

Challenge

Design and perform an investigation to determine whether the amount of rock material carried in the river water appreciably impacts the kinetic energy

Questions

1. What percentage of the river water's mass is sediment?
2. What percentage increase does this have on the water's kinetic energy?
3. Can you think of some situations where a sediment/water mix will have a significantly higher kinetic energy assuming the same velocity? Would the fluid in these situations behave differently?

Assumptions

The density of typical river sediment is 2650 kg/m^3

The density of water is 1000 kg/m^3

The total mass of the river sample consists only of water and sediment.

Tsunami

Students investigate the relationships between velocity, wavelength, amplitude and depth for water waves. They apply their observations to a tsunami and calculate the expected wave height and arrival time.

Core curriculum skills

Wave properties of wavelength, amplitude, velocity

Manipulating variables and using formulae

Earth science literacy principles

Natural processes affect the environment and people.

Studying natural hazards can provide valuable information to mitigate their effects.

Contents

"Tsunami" investigation

Teaching notes

1. Prepare in advance the materials needed to construct a simple wave tank. Suggestions are given below.
2. Allow time for students to experiment and record results. Facilitate teaching or review of experimental techniques as needed, e.g. control of variables. Waves in a small tank may travel too fast to be easily observed. You can video the wave and watch it in slow motion.
3. Ensure in Part 3 of the investigation that students are able to manipulate the equations.
4. Visit the National Oceanic and Atmospheric Administration (NOAA) Center for Tsunami Research web page for the 2004 Indonesian tsunami and view animations of wave propagation around the world: http://nctr.pmel.noaa.gov/indo_1204.html
5. Amplitude is correctly defined as the distance from the undisturbed state to the wave peak, but tide gauges report amplitude as crest-to-trough. The true wave amplitude is ½ of this figure.

Extensions

- Investigate historical tsunamis around the world and regions at risk.
- Research evacuation plans and tsunami-proofing of buildings.

Resources

Wave tank suggestions

The ideal wave tank is a large rectangle, wide and long, at least 10 cm deep with as large an area as possible. Suggestions include:

1. Clear plastic tub such as an under-bed storage box.
2. Eavestrough section.
3. A cardboard box lined with a plastic sheet. This has the advantage of being adaptable. If it is expandable, it will be easier to store and transport.

The wave generator should be a flat, uniform block the same width as the tank. A piece of 2x4 lumber would be suitable.

Solutions to student activity

Tsunami

Part 1: Waves and Water Depth (Step 8)

8. Plot graphs showing how velocity, wavelength and amplitude vary with water depth.

   Velocity and wavelength decrease, and amplitude increases as the water depth decreases.

Part 2: Circular Waves (Steps 11-12)

11. Assume the waves are a perfect circle. Take the point where the waves start to be the geometric origin. Write an equation that describes the positions x and y on the wave for each radius r.

    x2 + y2 = r2

12. Drop the marble in the same place and describe how the waves change as they pass into the shallower water.

    The waves will slow down, be closer together and of larger amplitude. They may also change direction (refract) depending on the orientation of the block to the oncoming waves.

Part 3: Tsunami (Steps 13-15)

13. a) Calculate the velocity of the tsunami at its source.

$v = \sqrt{(g \times d)}$

$= (9.81 \times 3000)^{1/2} = 171$ m/s

b) Based on the calculated velocity in 13. a), what is your estimate for how long this wave would take to reach the nearest beach, which is 500 km away?

500 km = 500 000 m

Velocity = distance/time

171 m/s = 500 000 m/time s

Time = 500 000 /171 s = 2923 s = 48 minutes

c) Calculate the expected amplitude when the wave enters water only 10 metres deep near a beach. Use the formula:

$As/Ad = \sqrt{(Vd/Vs)}$

Where: As = Amplitude of the wave in shallow water

Ad = Amplitude of the wave in deep water (2 m)

Vd = Velocity of the wave in deep water = 171 m/s from part a

Vs = Velocity of the wave in shallow water

$Vs = (9.81 \times 10)^{1/2} = 9.9$ m/s

$As = (171 / 9.9)^{1/2} \times 2 = 8.3$ metres

14. What will affect the actual time of arrival of a tsunami at the beach?

    Ocean floor topography and coastal geography will affect the wave velocity and arrival time.

15. How is the energy of the tsunami dissipated as it reaches the land?

    The energy will be dissipated by friction as the water floods the coast, and by kinetic energy and plastic deformation of buildings, trees, sediment and debris (cars, boats, etc.) that the tsunami moved and damaged.

Tsunami

Materials

Wave tank
Wave generator
Ruler
Stopwatch
Marble
Plastic tub or wooden block, about 3 cm deep
Graph paper

Investigation

Part 1: Waves and Water Depth

1. Add 1 cm of water to the tank.
2. Put the wave generator at one edge of the tank. Practice making a wave by rapidly pushing the wave generator about 1 cm down into the water and removing it. Let the water settle between each wave. When you can do this consistently, move onto the next step.
3. Measure the time for one wave to reach the opposite side of the tank. Repeat your measurement at least 3 times.
4. Measure the horizontal distance between two peaks, which is the wavelength.
5. Measure the vertical distance from a peak to a trough. Divide this number by 2 for the wave amplitude.
6. Repeat steps 3, 4 and 5 for water depths of 2 cm, 3 cm and 4 cm. Keep the movement of the wave generator constant for each water depth.
7. Measure the distance that the waves have travelled and use this to calculate the average velocity for each water depth. Velocity = distance/time
8. Plot graphs showing how velocity, wavelength and amplitude vary with water depth.

Observations

Water Depth (cm)	T_1 (s)	T_2 (s)	T_3 (s)	T_{av} (s)	Wavelength (cm)	V_{av} (cm/s)

Part 2: Circular Waves

9. With 4 cm of water in the wave tank, drop a marble into its centre. Observe the waves produced.
10. Calculate the spreading rate of the waves by measuring how the radius changes with time.
11. Assume the waves are a perfect circle. Take the point where the waves start to be the geometric origin. Write an equation that describes the positions x and y on the wave for each radius r.
12. Place a wooden block or plastic tub in one corner of the wave tank to simulate a coastal region. Drop the marble in the same place and describe how the waves change as they pass into the shallower water.

Part 3: Tsunami

A tsunami has been generated in the Pacific Ocean by an earthquake in waters where the average depth is 3000 metres.

As the bottom of the ocean moved during the earthquake, the sea surface above was pushed up. Gravity pulled the water back down and this started the tsunami wave motion. The velocity (v) of a tsunami is related to the acceleration due to gravity (g) = 9.81 m/s2) and water depth (d):

$$v = \sqrt{(g \times d)}$$

13. a) Calculate the velocity of the tsunami at its source.

    b) Based on the calculated velocity in 13. a) what is your estimate for how long this wave would take to reach the nearest beach, which is 500 km away? Hint: take care to use the same units in your calculation.

    The tsunami amplitude at the source is 2 metres, which may not even be noticed by ships on the ocean. As the wave enters shallower water, however, the bottom of the wave is slowed by friction with the sea floor, and the wavelength and velocity decrease. The front of the wave slows first while the back of the wave piles into it increasing the wave's amplitude.

    c) Calculate the expected amplitude when the wave enters water only 10 metres deep near a beach. Use the formula:

    $$A_s/A_d = \sqrt{(V_d/V_s)}$$

    Where: A_s = Amplitude of the wave in shallow water

    A_d = Amplitude of the wave in deep water (2 m)

    V_d = Velocity of the wave in deep water

    V_s = Velocity of the wave in shallow water
14. What will affect the actual time of arrival of a tsunami at the beach?
15. How is the energy of the tsunami dissipated as it reaches the land?

Landslides

Students model and investigate a landslide and calculate the forces and energy involved. They use the basic equations of motion to locate a sound source, in this instance a landslide.

Core curriculum skills

Equations of motion: distance, acceleration, velocity

Potential and kinetic energy, work

Measurement: mass, density, volume, angle, distance

Converting units of measurement

Manipulating formulae

Earth science literacy principles

Natural processes are continuously changing the landscape around us.

Studying natural hazards can provide valuable information to mitigate their effects.

Human activities can affect the Earth's natural systems.

The Earth is a complex system of integrated and interacting subsystems, including the water and rock cycles.

Contents

"What is a Landslide?" information pages

"Landslides across Canada" images

"Landslides in Flat Land" information page

"Investigating a Landslide" experiment

"Looking More Closely at the Frank Slide" information page

"Physics of the Frank Slide" assignment

"Location Using Sound Waves" assignment

Teaching notes

1. Distribute the "What is a Landslide?" information page and "Landslides Across Canada" images. Introduce the concept of landslides as a natural hazard. Discuss the risks to people and property, and the remedial measures described on the information page.

2. Have students complete the "Investigating a Landslide" experiment that guides them through the steps required to calculate the mechanics of a landslide.
3. Study the "Landslides in Flat Land" information page and compare this method of causing landslides (erosion at the base) to the students' investigation (water saturation).
4. Have students complete the "Looking More Closely at the Frank Slide" assignment as an assessment of how they independently apply the mechanics calculations learned.
5. Have students complete the "Location Using Sound Waves" assignment, applying velocity, distance/time relationships and geometric triangulation. Note: students will need maps of Alberta for this assignment.

Extensions

- Investigate how changing the rock mixture or removing the plastic wrap in "Investigating a Landslide" changes the landslide.
- Model and test engineered solutions that can be applied to slopes to reduce the landslide hazard.
- Map landslide hazard across Canada. For example, download: Geological Survey of Canada, Open File, 3712, Landslide disasters in Canada, 1840-1998, Evans, S. G., 1999.
- Predict and investigate why sound waves move faster in warmer air.
- Use the triangulation method to locate earthquake epicentres.

Solutions to student activities

Investigating a Landslide

1. a) What is the volume of rock involved in the slide?

   *Volume = length * width * depth*

   b) What is the mass of rock involved in the slide?

   Volume x Density = Mass (kg)

2. What is the F_g on this mass of rock?

   $F_g = mg = (m \text{ kg} \times 9.8 \text{ m/s}^2)$ *Newtons*

3. a) How long would it take for an object to free fall through the same vertical height change as the slide?

   $d = v_i t + (1/2) at^2$

   $a = 9.8 \text{ m/s}^2$ *and initial velocity is zero*

$d= (1/2)\ at^2 = 0.5 * 9.8\ m/s^2 * t^2$

$t^2 = d * 2 / 9.8$

$t = \sqrt{(d * 2 / 9.8)}$ seconds

b) What would its velocity be at point of impact? Air friction is assumed to be negligible.

$a = (V_f - V_i)/t$

where $V_{i\ is}$ zero and t calculated in Part a)

$V_f = 9.8 * t$ m/s

4. What is the loss of potential energy in the rockslide as it falls?

   *$E_p = mgh = mg\ (H_i - H_f)$ and is measured in Joules (kg*m/s)*

   Where $(H_i - H_f)$ is the vertical elevation of the hill

   $E_p = m * (9.8 m/s^2) * (H_i - H_f)$

5. a) When the slide reaches the bottom what is its kinetic energy?

   The loss of potential energy is equivalent to the gain in kinetic energy so at the bottom of the slope:

   $E_k = \Delta E_p$ as calculated in question 4.

   b) What is its overall velocity?

   $E_k = (1/2)\ mv^2$

   $v^2 = E_k * 2$

   $v = \sqrt{(E_k * 2)}$

   c) What are its horizontal and vertical velocity components immediately before reaching the bottom of the slope?

   Slope is inclined at Θ degrees, So that:

   Vertical velocity component = $(\sin \Theta) * v$

   Horizontal velocity component = $(\cos \Theta) * v$

Physics of the Frank Slide

1. What is the mass of the rock involved in the slide?

   Volume x Density = Mass

   (30 million m^3 of rock) x (2650 kg/ m^3) = 7.95×10^{10} kg

2. What is the F_g on this mass of rock?

   Fg = mg = (7.95 x 1010 kg) x (9.8 m/s^2)

   = 7.8×10^{11} kgm/s^2 (N)*

3. How long would it take for an object to free fall from the same elevation as the top of Turtle Mountain to ground level? What would its velocity be at point of impact? Air friction is assumed to be negligible.

   $a = 9.8\ m/s^2$

   $d = vit + (1/2)at^2$ but since initial velocity is zero

   $d = (1/2)at2 = 0.5*9.8\ m/s2 * t^2$

   $t^2 = 885m * 2 / 9.8\ m/s^2$

   $t = 13.4$ seconds to impact

   Velocity at point of impact is determined by using the formula:

   $a = (Vf-Vi)/t$

   where Vi is zero and t=13.4 seconds

   $Vf = 9.8\ m/s^2 * 13.4$ seconds

   = 131 m/s

   = 37 km / hour

4. What is the loss of potential energy in the rockslide as it falls from Point A to Point B?

   *Ep = mgh = mg (Hi-Hf) measured in Joules (kg*m/s)*

   where Hi=2195m and Hf=1310m.

   $Ep = (7.95 \times 1010\ kg)(9.8 m/s^2)(2195-1310m)$

   *=6.895 x1014 kg*m/s (J)*

5. Just as the slide reaches the valley floor at Point B what is its kinetic energy? What is its overall velocity? What are its horizontal and vertical velocity components immediately before reaching Point B?

   The loss of potential energy is equivalent to the gain in kinetic energy so at Point B

   $\Delta Ep \sim Ek$

   So Ek = 6.895 x 1014 J. By comparison the Hiroshima atomic bomb explosion released about 8.3 x 1013 J, equivalent to 12% of the kinetic energy generated in the Frank Slide. The Mount St. Helens eruption (initial explosion) released 1.3 x 1018 J or 1885 times more energy. The meteor impact event at Chicxulub Crater in the Yucatan Peninsula that is thought to have caused the mass extinction of the dinosaurs was created by an asteroid 10 km in diameter that released 3.7 x 1023 J. The size of forces in nature is almost beyond our ability to imagine.

Since Ek= (1/2) mv^2 then Ek = 6.895 x 1014 = (1/2) (7.95 x 1010) v^2

v2=18769 (m/s)^2

v=132 m/s or 37 km/hour

Slope is inclined at 25 degrees, So that:

*(Sin 25°) * (37km/hr) = 15.6 km/hr vertical velocity and*

*(Cos 25°) * (37 km/hr) = 33.5 km/hr horizontal velocity for the slide at Point B.*

6. Calculate the net work being done by the slide.

   Apply the work energy relationship:

   *W =F * d = ΔEk = (1/2)m (Vf^2-Vi^2)*

   *=(1/2)(7.85 x 1010 kg) * (132 2 – 0 m/s) = 6.93 x 1014 J*

7. Once the slide reaches the valley floor it continues on its cushion of air for 2000 m before stopping. How long does it take to stop, assuming uniform deceleration? What is the rate of deceleration? What is the friction force required to bring this mass to a halt in this distance, and what would the coefficient of friction be?

   Vi = 37 km/hour or 132 m/s and Vf = 0

   *d = (Vf+Vi) * t / 2*

   *t = 2d / (Vf+Vi) = 2 * (2000) / (132 + 0) = 30.3 seconds for slide to come to a stop*

   The rate of deceleration can be determined by using:

   a = (Vf-Vi) / t = (0-132) / 30.3 = - 4.4 m/s^2

   Force of friction can be calculated by applying W=ΔEk and Ff=W/d

   Ff=ΔEk / d = (6.895 x 1014) / (2000 m) = 3.448 x 1011 N

   The coefficient of friction can be determined by Ff = μFN where FN=mg.

   Therefore μ= Ff /mg= (3.448 x 1011 N)/(7.95 x 1010 / 9.8 m/s^2)

   So μ=0.44

8. If the rockslide hit and transferred all of its kinetic energy into a 3000 kg rubber ball (approximate weight of a school bus) how fast would that ball go?

   Must use the laws of conservation of energy to resolve this problem.

   Before the collision:

(slide) (ball)

$E_k = (1/2)\ m\ v^2 + (1/2)\ m\ v^2$

Where the ball has zero kinetic energy and the slide contains:

$E_k = (1/2)\ m\ v^2 = 6.895 \times 10^{\wedge 14}$ *kg*m/s (J)*

After the impact (assuming elastic collision) the slide now has zero kinetic energy so

$E_k = 6.895 \times 10^{14}$ *kg*m/s (J)= (1/2) (3000kg) ** v^2

$v = 6.8 \times 10^5$ *m/s or 188,340 km/hr.*

(This is more than enough velocity to escape the Earth's atmosphere.)

Location Using Sound Waves

1. How far away is Calgary from the source?

   Sound waves travel at a constant velocity in an expanding circle away from the source.

   Disaster struck the mystery town at 4:10.00 a.m., and the sound arrived in Calgary at 4:18.07 a.m. Therefore it took 488 seconds for the sound to arrive.

   $V = d / t$

   $d = V \times t$

   $d = (332\ m/s) \times (488\ s) = 162016\ m$ *or 162 km.*

   Therefore, Calgary is 162 km away from the source of the sound.

2. Use the distance from each town that reported the sound to locate the source.

   Use the time of arrival of the sound at each town to calculate the distance from the source:

Cranbrook	*100 km*
Pincher Creek	*38 km*
Calgary	*162 km*
High River	*115 km*
Lethbridge	*120 km*
Brooks	*220 km*

Draw a circle around each town, the radius of which is the distance from source.

The point where are all the circles intersect is the source, in this case the town of Frank.

3. What is the minimum number of towns reporting the time required to pinpoint the source?

   A minimum of three towns is required, as only two towns will give you two possible locations.

4. The velocity of sound is 0.6 m/s faster with every degree Celsius above freezing. When would the sound arrive in Calgary if the temperature were 20 degrees Celsius?

   Given that V= 332 m/s at 0 degrees Celsius

   V (20) = 332 m/s + (0.6 x 20) = 344 m / sec

   t = d /V = (162000 m) /(344m m/sec) = 470 seconds

   The sound would have arrived in Calgary at 4:17.50 a.m.

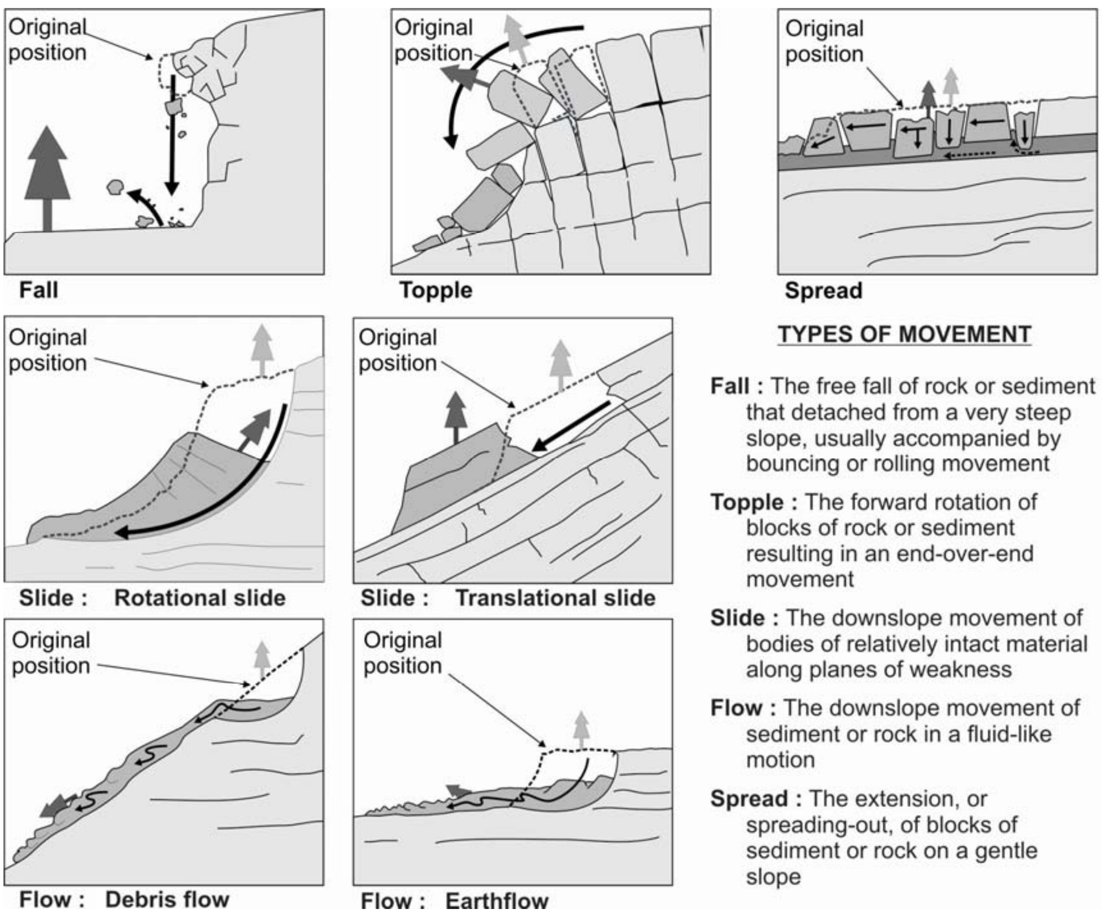
What is a Landslide?

A landslide is the down slope movement of bedrock and/or loose sediment (i.e. clay, sand, gravel and boulders), under the influence of gravity. Landslides can be found everywhere, even in areas with low relief. They can happen on land or underwater; be large or small, rapid or slow; and generally occur without warning. There are many failure mechanisms and triggering causes, and local geological and topographical conditions determine which type of landslide may happen in a specific region.

What Causes Landslides?

Landslides can be triggered by heavy rainfall or rapid snow melt, both of which increase river erosion and the water content of the sediment or rock layers. Earthquakes are another cause, as are freeze-thaw action on rock faces, and human activities. Excavation at the base of slopes, placing excess fill at the top of slopes, deforestation, stream modification, and excessive irrigation can all contribute to causing landslides.

Types of Landslide Movement



Source: J.M. Aylsworth, Geological Survey of Canada

Landslides in Canada

Since1840, landslides in Canada have resulted in over 600 fatalities, including the destruction of several communities, and they have caused billions of dollars in damage to buildings and transportation systems. The hazard presented by landslides involves not only failure of ground beneath a structure and impact or burial by moving debris, but also secondary effects such as landslide-dammed floods and landslide-generated waves.

Some areas in Canada are at higher risk of landslides. Many mountain valleys in British Columbia have steep sides and are vulnerable to rockfalls and debris flows that disrupt transportation and communications across the province. Prairie valleys are susceptible to slow sliding movements along planes of weakness in soft, Cretaceous shale bedrock. For example, a slide in Cretaceous shales under the north abutment collapsed the Alaska Highway suspension bridge over the Peace River in 1957 – this was Canada's most expensive landslide ($60 million). The South Saskatchewan River is actively eroding the base of its banks, which in many places are capped with clay that slips easily. The Bow and Elbow rivers around Calgary have eroded steep valleys through glacial till,and these banks are unstable and fail when water-saturated. The St. Lawrence Lowlands from Ottawa to Quebec City overlie a sensitive marine sediment called Leda clay, which is susceptible to landslides when the clay is disturbed. Leda clay landslides are unusual in that they can occur in relatively flat land. The illustrations in "Landslides in Flat Lands" show a possible sequence of events that could cause a type of landslide called an earthflow.

The worst landslide disaster in Canada occurred in the early morning of April 29, 1903. In less than two minutes, 30 million cubic metres of rock slid down Turtle Mountain in southern Alberta. The landslide covered much of the town of Frank with a pile of boulders 150 metres deep and 1 kilometre wide. The largest boulders were over 15 metres long. At least 70 people were killed instantly as the rock flow buried their houses.

Reducing the Damage from Landslides

By understanding the mechanics involved in landslides, preventative, engineered solutions can be constructed in areas of known risk. Steep, rocky slopes can be made more stable by removing or bolting threatening rock. They can also be covered with metal mesh or sprayed with concrete to prevent loosened rock from reaching structures below. Holes drilled into the slope allow groundwater to drain more easily, reducing water pressure that might trigger a rockfall. Physical containment or diversion structures can be constructed to protect communities and critical transportation from debris flows. On unstable river banks, a berm of coarse rock placed along the river edge holds the slope in place and prevents bank erosion, or slope angles can be reduced and slope drainage improved. In many cases the best solution may simply be avoidance of risk by restricting or controlling development on hazard slopes.

Landslides across Canada

Five Mile Creek, Banff National Park, Alberta

The August 1999 slide is located approximately 5 km west of Banff, Alta. It was unexpected, as it was the result of intense rainfall that was unrecorded by local weather stations. Debris blocked the highway for 24 hours, delaying thousands of travellers in Banff while cleanup took place.

Landslide type: Debris flow

Photo: R. Couture, GSC, 2002

Muskwa-Chisca landslide, British Columbia

A complex slide occurred in the summer of 2001 at the confluence of the Muskwa and Chisca rivers. It started as a rotational movement in sandstone and shale, and ended as a flowslide in cohesive sediment.

Landslide type: Complex

Photo: M. Geertsema, BC Ministry of Forests, 2002

Cecil Lake Road landslide, Fort St. John area, British Columbia

This landslide occurred July 2001, and partially blocked the highway for four weeks. Major transportation problems resulted as this highway is a crucial link for Fort St. John, the oil and gas fields northeast of Fort St John and Alberta border communities. The slide was triggered by a combination of weather conditions and other factors. It left a horseshoe-shaped scar on the cliff.

Landslide type: Slide

Photo: R. Couture, GSC, 2001

Pitts Memorial Drive, St. John's, Newfoundland

This rockfall closed the road for several hours in April 1997 while cleanup crews removed the debris. No one was seriously injured.

Landslide type: Rockfall

Photo: David Liverman,

Newfoundland Geological Survey, 2002

Lemieux Landslide, South Nation River valley, Ontario.

The Lemieux Landslide, which occurred on June 20, 1993, was a retrogressive landslide where the headwall eroded back into the valley side, and the landslide debris flowed towards the river, away from the scarp. It caused about 2.5 to 3.5 million m^3 of sediment to flow into the valley of the South Nation River, burying the valley bottom for 1.6 km downstream and 1.7 km upstream. The landslide debris dammed the river, as seen in the foreground. Landslide scars, like the hollow in the background, are common in the Ottawa Valley and the St. Lawrence Lowlands areas where the ground surface is underlain by sensitive glacio-marine sediments (Leda clay).

Landslide type: Retrogressive

Photo: G. Brooks, GSC, 1993

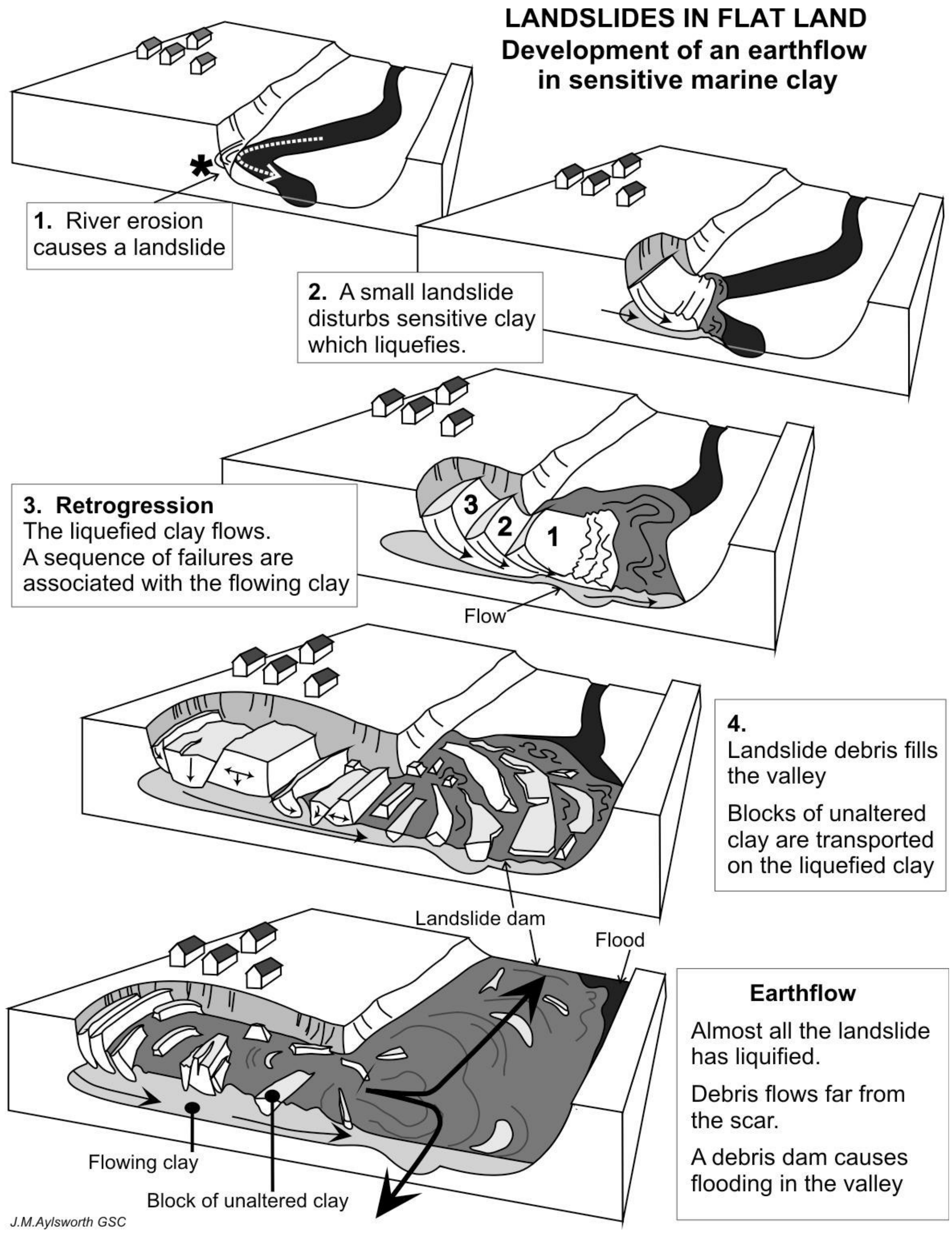
Frank Slide, Alberta.

This landslide occurred at 4:30 am on April 29, 1903 when 30 million m^3 of rock broke free from the east side of Turtle Mountain. The event buried part of the town of Frank and 2 km of the Canadian Pacific Railway. Lasting only 100 seconds, the Frank Slide is Canada's worst landslide disaster. It killed at least 70 people, although more fatalities are suspected because of the possible presence of unregistered migrant workers in Frank at the time.

Landslide type: Rockslide

Photo: M. Bovis, University of British Columbia, 2002

All images and information from the Geological Survey of Canada (GSC) Photo Collection



Geoscape Ottawa-Gatineau Teacher Resources http://geoscape.nrcan.gc.ca

Investigating a Landslide

Materials

Waterproof container, e.g. dishpan eavestrough section
Rock material (mixture of soil, pebbles, sand, gravel)
Plastic wrap
Ruler
Protractor
Volume measure
Balance scales
Spray bottle
Water

Safety

Clean up any water spills immediately. Wash your hands after completing this activity.

Procedure

1. Use the rock mixture to create a steep hill at one end of the container, extending the full width and no longer than its height, i.e. a slope of 45 degrees.
2. Cover this hill with plastic wrap, securing it firmly around the edges.
3. Add another rock layer of uniform thickness on top of the plastic wrap, extending the hill to no further than ½ of the distance along the container.
4. Record the parameters of your model:

   Density of rock material in g/cm^3

   Width of hill in cm

   Length of hill in cm

   Thickness of the layer above the plastic wrap in cm

   Angle of slope in degrees
5. Fill the spray bottle with water.
6. Spray the top of the slope with water. Count how many sprays until the slope collapses. Observe the pattern of collapse: does it slip, topple over, flow or crumble?
7. Estimate the dimensions of the landslide:

   Width

   Length

   Thickness

   Vertical height change = highest point – lowest point

Calculations

1. a) What is the volume of rock involved in the slide?

   b) What is the mass of rock involved in the slide?
2. What is the F_g on this mass of rock?
3. a) How long would it take for an object to free fall through the same vertical height change?

   b) What would its velocity be at point of impact? Air friction is assumed to be negligible.
4. What is the loss of potential energy in the rockslide as it falls?
5. a) When the slide reaches the bottom, what is its kinetic energy?

   b) What is its overall velocity?

   c) What is the horizontal and vertical velocity immediately before reaching the bottom?

Looking More Closely at the Frank Slide

On April 29, 1903, early in the morning most of the people who lived in Frank, a coal mining town in the foothills of the Rockies, were asleep. The only ones awake were 17 miners working the early shift in a coalmine at the base of Turtle Mountain. The snows had been heavy that winter, but it was finally warming up, resulting in a lot of meltwater. The day before the landslide, it cooled down to the freezing point and water-filled fissures expanded as the water turned to ice. Perhaps this, in combination with a small earthquake or even structural weakening by the extensive mine works at the mountain's base, was the trigger for the landslide. Whatever the cause, at precisely 4:10 a.m., death rumbled down on the town of Frank.

About 30 million cubic metres of rock slid from the south face of Turtle Mountain and over the coal mine entrance. The slide then wiped out much of the town and continued up the side of the opposite mountain, before returning to the valley floor and settling on the town, the road and mine entrance. Survivors reported great blasts of air emitting from the sliding debris. This suggests the slide was air-lubricated, with the rocks and debris sitting on a cushion of air and speeding along much like a hovercraft travels over water. The whole slide was over in less than 100 seconds.

The end result was that much of Frank was buried under a pile of boulders 150 metres deep and 1 kilometre wide. The largest boulders were over 15 metres long. Seventy people were killed instantly in this town of 600. Sid Choquette, an employee for the Canadian Pacific Railway, realized shortly after the slide that the debris covered the railway tracks. Knowing that the passenger train, the Spokane Flyer, was due, Choquette ran to where the track was still complete and flagged it down. If he had not, the disaster would have been tragically compounded by the train running full speed into the landslide debris. Amazingly, the 17 coal miners trapped by the slide were able to dig themselves free 14 hours later. Although struck with an overwhelming disaster, the resourceful townspeople of Frank were able to re-establish the railway link within 3 weeks, with a highway built through the slide by 1906.

Today, the Frank Slide Interpretive Centre in Crows Nest Pass, Alberta, provides historical exhibits about the slide and there are short trails down into the slide zone.
http://www.frankslide.com/

Created by Philip Benham for The Burgess Shale Geoscience Foundation

Physics of the Frank Slide

Assumptions

The slide detaches from the top of Turtle Mountain at Point A: elevation 2195 m above sea level.

Slide hits the valley floor at Point B: elevation 1310 m above sea level.

The volume of rock involved in the slide is 30 million m^3.

The rock is mainly limestone with minor porosity and has a density of about 2.65 g/cm^3 or 2650 kg/m^3

The slope the slide falls down is 25 degrees

Due to the cushion of air described in the information page, the friction is essentially zero.

Questions

1. What is the mass of the rock involved in the slide?
2. What is the F_g on this mass of rock?
3. How long would it take for an object to free fall from the same elevation as the top of Turtle Mountain to ground level? What would its velocity be at point of impact?
4. What is the loss of potential energy in the rockslide as it falls from Point A to Point B?
5. Just as the slide reaches the valley floor at Point B what is its kinetic energy? What is its overall velocity? What are its horizontal and vertical velocity components immediately before reaching Point B?
6. Calculate the net work being done by the slide.
7. Once the slide reaches the valley floor it continues on its cushion of air for 2000 m before stopping. How long does it take to stop, assuming uniform deceleration? What is the rate of deceleration? What is the friction force required to bring this mass to a halt in this distance, and what would the coefficient of friction be?
8. If the rockslide hit and transferred all of its kinetic energy into a 3000 kg rubber ball (approximate weight of a school bus), how fast would that ball go?

Created by Philip Benham for The Burgess Shale Geoscience Foundation

Location Using Sound Waves

Early in the morning of April 29, 1903, you are roused from your sleep by a loud rumbling. You look at the clock on the wall and grimace at the time: 18 minutes and 7 seconds past 4:00 a.m. (04:18.07). You rise from your bed and look outside at the city of Calgary, but you can't see anything that could have caused such a noise. After a couple of minutes, the sound dies away and you go back to sleep. Some time after breakfast, the Chief of Police knocks on your door.

"You're our expert scientist round here. I need your help. We've got a real puzzle on our hands." he says. "I guess you heard the explosion or whatever it was this morning. Well, we got a telegraph, or rather part of it and all it said was: "Terrible disaster… at 4:10 a.m. precisely our town was hit. Need help."

The Chief clears his throat and says "We're rounding up a rescue team, if you can just tell us where we need to go. You see, the telegram didn't say what town! Many other towns heard the noise, however, and we have telegraphs from them saying precisely when they heard it."

"I'll get right on it," you say, as you pull your trusty map out of a desk.

Here is the information received from the other towns:

- Cranbrook reports hearing a loud cracking noise around 04:15.01 a.m.
- Pincher Creek heard the same sound around 04:11.54 a.m.
- High River hears a noise around 04:15.46 a.m.
- Settlers in Brooks note a low rumble around 04:20.03 a.m.
- Lethbridge hears a boom around 04:16.01 a.m.

You know the velocity of sound is 332 m/s at 0 degrees Celsius, which is what you judge the temperature to be outside.

You also have a map of the region locating the towns that reported the noise

Questions

1. How far away is Calgary from the source?
2. Use the distance from each town that reported the sound to locate the source. Hint: you will need a compass, ruler and a map of Alberta.
3. What is the minimum number of towns reporting the time required to pinpoint the source?
4. The velocity of sound is 0.6 m/s faster with every degree Celsius above freezing. When would the sound arrive in Calgary if the temperature were 20 degrees Celsius?

Created by Philip Benham for The Burgess Shale Geoscience Foundation

Supercontinent Cycles

Using GPS data of surface velocities, students calculate estimates for the age of the Atlantic Ocean, and predict when it will close up again.

Core curriculum skills

Statistical analysis of mean and range

Linear graphs and functions

Manipulating equations

Earth science literacy principles

The Earth is a complex system of integrated and interacting subsystems, including tectonic processes.

Many natural processes are cyclic and repeat over time.

Earth is a dynamic entity that changes over time, including its landscape and surface features.

Contents

"The Supercontinent Cycle" information page

"Spreading Ridges around the World" information page

"The Disappearing Ocean" assignment

Teaching notes

1. Show online photographs or videos of volcanic eruptions in Iceland, e.g. http://www.telegraph.co.uk/earth/earthvideo/7544497/Icelandic-volcano-spews-more-lava-dramatic-pictures.html Discuss that this volcanism is caused by tectonic plates moving apart. Show a cross-section of the Earth's layers and identify that the tectonic plates are the lithosphere, which "floats" on top of the asthenosphere.
2. Have students read "The Supercontinent Cycle" to appreciate the opening of oceans due to spreading ridges, and the subsequent cyclical closure of oceans.
3. Look at the images on the "Spreading Ridges around the World" information page. Discuss the patterns of age of rocks and spreading velocity.
4. The available data file for question 11 of "The Disappearing Ocean" contains approximately 750 velocity measurements. The data can be imported into a

spreadsheet program. Alternatively, students could select individual stations around the world and perform the calculations manually.

Extensions

- Explore maps and animations from the PALEOMAP Project http://www.scotese.com/

Solutions to student activity

The Disappearing Ocean

1. Calculate the mean velocity from data provided for locations in and around the Atlantic Ocean.

   19.9 mm/yr

2. Use a map of the world and establish a representative width for the Atlantic Ocean.

   Range is from 2800 km to 6500 km. Average = 4650 km

3. Knowing that velocity = distance/time and assuming that the velocity has been constant as the ocean has grown, calculate the time needed for the Atlantic Ocean to reach its present size.

   Current width of ocean = 4650 km

   Each side of spreading ridge has moved

   = 4650/2 = 2325 km

   2325 km = 2 325 000 000 mm

   Time to move this distance

   = 2 325 000 000/19.9 = 116 834 170 years

   = 117 million years

4. How many years until the Atlantic Ocean reaches its widest point?

   Time remaining for spreading portion of cycle = 250 -117 = 133 million years

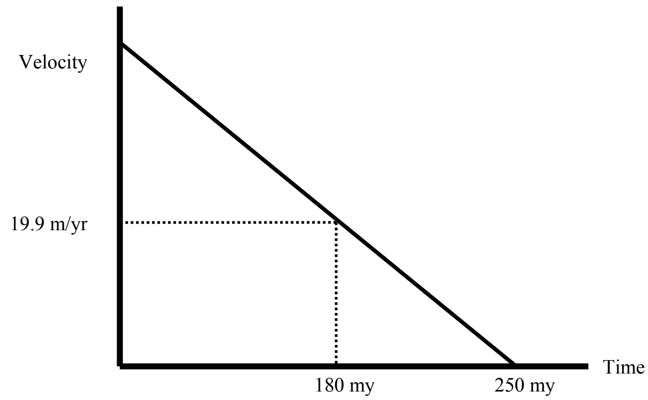
5. How many years until the Atlantic Ocean disappears?

   Time remaining until the it closes = 500 – 117 = 383 million years

6. Sketch a graph that shows a constant decrease in velocity with time.

7. Mark on the graph the point at time = 250 million years and velocity = 0.

8. The oldest age of rocks dated in the North Atlantic is in the order of 180 million years. Mark this point on the graph; with the corresponding average velocity you calculated in question 1.



9. From the relationship for a straight-line graph, calculate the initial spreading velocity when the Atlantic Ocean began to open.

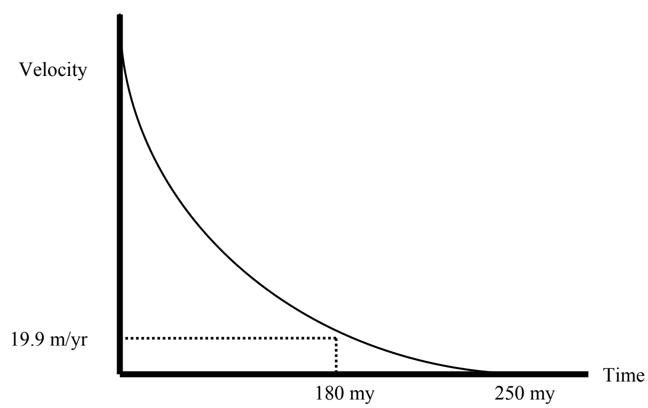
Straight-line graph has equation $y = mx + c$

$m = (y_2 - y_1)/(x_2 - x_1) = (0 - 19.9)/(250 - 180) = -0.28$

Rearranging the line equation for $c = y - mx$

$= 19.9 - (-0.28 * 180) = 70.3$ *mm/yr*

10. Sketch a graph showing velocity decreasing non-linearly with time. How would this model affect the initial spreading velocity?



If this is the function of velocity with time, the initial spreading velocity is greatly increased.

11. a) What is current mean value of global motion?

    27.6 mm/yr

    b) What is range?

    1.5 mm/yr to 77.9 mm/yr

    c) Which geographic locations have the highest velocity?

    Depends on data plotted. Hawaii, Australia and Indonesia are all examples.

The Supercontinent Cycle

Why does Iceland have volcanic eruptions? The answer is simple: "Location, location, location." Iceland sits directly above the Mid-Atlantic Ridge, a spreading ridge where the tectonic plates that make up the outer layer of the Earth are moving apart. New rock is being formed here, as magma surges up into fissures caused by this spreading.

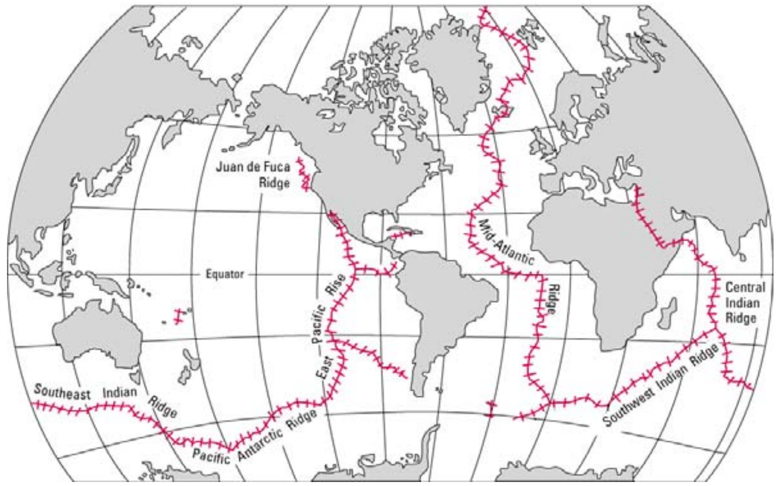
If the Atlantic Ocean is getting wider in the middle, what's happening at its edges? Is the Earth getting bigger? Is something somewhere else being destroyed? The answer is that at the edge opposite to the spreading ridge, the tectonic plate is colliding with another plate. One plate gets pushed down under the other, and some rocks are indeed destroyed. As the plate moves deeper into the Earth, the rocks melt and become magma again.

An ocean does not keep getting wider forever. An internationally renowned Canadian geologist J. Tuzo Wilson (1908-1993) made a major discovery that changed how we understand the Earth's history. He identified a 500-million-year repeating cycle in the movement of continents and this is known as the Wilson Cycle. For 250 million years the continents move apart as the ocean spreads, and then the motion reverses. Over the next 250 million years the ocean closes, and all the land joins together as a supercontinent. The most recent supercontinent in Earth history was Pangea, which existed between about 300 and 150 million years ago, and there is evidence for at least 5 supercontinents previous to Pangea.

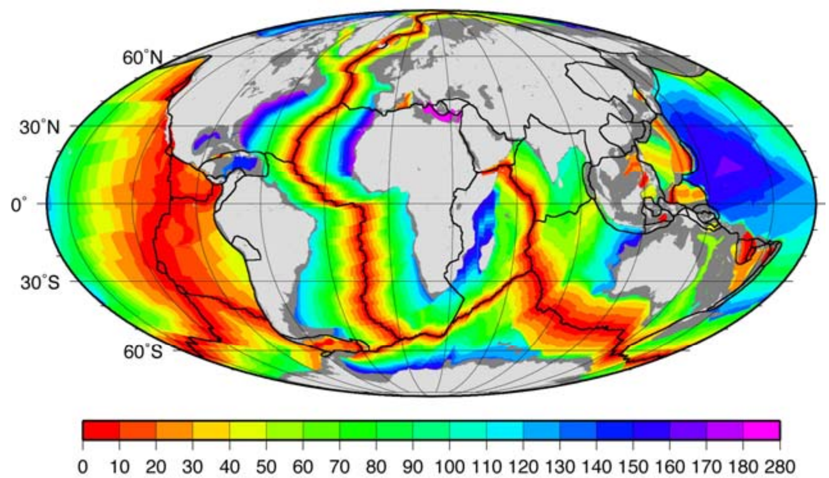
The driving force for plate tectonics is convection currents within the Earth's mantle. Although the precise mechanisms are not yet fully defined, it is thought that the relative strength of different convection currents in the mantle control the cycle of ocean spreading and closing.

Plate tectonics is a cyclic process that through Earth's history has created multiple supercontinents and continental breakups. Because of plate tectonics, our Earth is a dynamic system where rocks are constantly being recycled. Plate tectonics shapes our landscape, gives us mineral resources and geothermal energy, triggers earthquakes and volcanoes, and influences our climate through ocean thermal currents.

Spreading Ridges around the World



Source: USGS This Dynamic Planet



Muller, R.D., M. Sdrolias, C. Gaina, and W.R. Roest 2008.

Age, spreading rates and spreading symmetry of the world's ocean crust.

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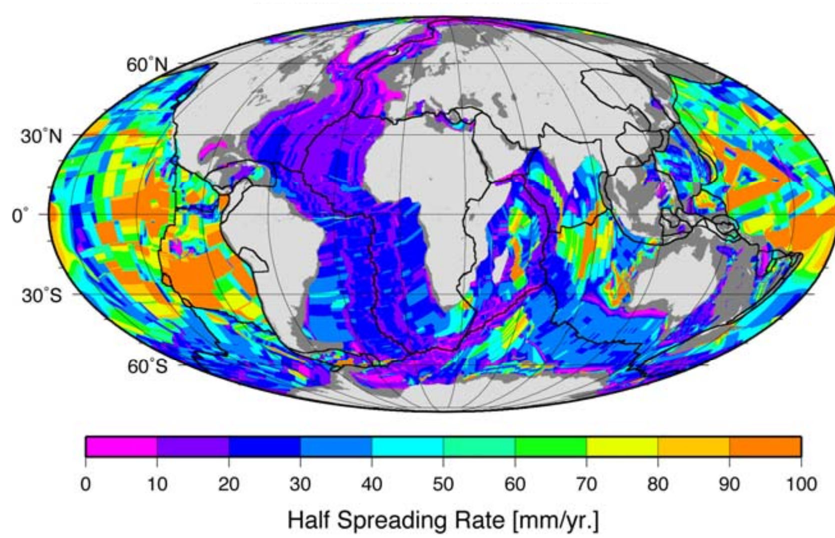


The Disappearing Ocean

Data for Atlantic Ocean Region

Station	Latitude	Longitude	Velocity (mm/yr)
ASC1	-7.95	14.41	12.52
BRMU	32.37	-64.69	14.47
GOUG	-40.35	9.88	25.45
HOFN	64.27	15.19	18.51
KELY	66.99	50.94	22.00
KIR0	67.88	21.06	21.17
MASP	27.76	15.63	21.26
NALL	78.93	11.86	17.81
REYK	64.14	21.95	23.93
REYZ	64.14	-21.95	23.07
SCH2	54.83	-6.83	19.73
STJO	47.59	-52.68	19.13

Source: http://sideshow.jpl.nasa.gov/mbh/series.html

How long until the Atlantic Ocean closes again?

1. Calculate the mean velocity from data provided for various locations in and around the Atlantic Ocean.
2. Use a map of the world and establish a representative width for the Atlantic Ocean.
3. Knowing that velocity = distance/time and assuming that the velocity has been constant as the ocean has grown, calculate the time needed for the Atlantic Ocean to reach its present size. Hint: the ocean floor spreads equal distances in both directions at once.
4. The Wilson cycle states that a typical time for a complete cycle (opening and closing) is 500 million years.

   How many years until the Atlantic Ocean reaches its widest point?
5. How many years until the Atlantic Ocean disappears?

How might the velocity have changed?

It is most likely that the velocity of oceanic crust moving away from the spreading ridge changes as the supercontinent cycle progresses. When the ocean is at its widest point, the velocity must be zero.

6. Sketch a graph that shows a constant decrease in velocity with time.
7. Mark on the graph the point at time = 250 million years and velocity = 0.
8. The oldest age of rocks dated in the North Atlantic is in the order of 180 million years. Mark this point on the graph, with the corresponding average velocity you calculated in question 1.
9. From the relationship for a straight-line graph, calculate the initial spreading velocity when the Atlantic Ocean began to open.
10. Sketch a graph showing velocity decreasing non-linearly with time. How would this model affect the maximum spreading velocity?

Global plate motion

11. Download GPS data for global locations from http://sideshow.jpl.nasa.gov/mbh/series.html

    a) What is current mean value of global motion?

    b) What is range?

    c) Which geographic locations have the highest velocity?

Glacial Retreat

Students analyze images of the Athabasca Glacier to estimate the change in its ice volume over time.

Core curriculum skills

Scaling

Measurement

Estimation

Earth science literacy principles

Earth scientists use many tools to observe and study the planet, including photography, remote sensing and computer technology.

The Earth is a complex system of integrated and interacting subsystems, including the water cycle.

Earth is a dynamic entity that changes over time, including its landscape and climate.

Contents

"Changes in the Athabasca Glacier" investigation

"Columbia Icefield" PowerPoint slideshow (digital version only)

Teaching notes

1. The PowerPoint slideshow can be used to introduce the task or to facilitate discussion afterwards. It includes a 3D image of the Columbia Icefield, additional historical photographs of the Athabasca Glacier, and a satellite image showing the icefield, its drainage and reservoirs.
2. The task is presented as a challenge, with minimal guidance. As needed, provide prompts or hints to assist students and to structure their investigation.
3. Facilitate discussion as to what has caused the observed changes in the glacier. Glaciers grow if the volume of snow added annually is greater than the volume melting, and they recede if the volume added is less. There are two essential variables: snowfall (precipitation) and ice melting (temperature). Have students describe the larger-scale impacts of the glacier receding by considering the current demands on the icefield; e.g. natural ecosystems, hydroelectric power generation, drinking water, aboriginal rights to water, trans-border water agreements.

Extensions

- Research other global locations where glaciers are retreating, e.g. the Alps, New Zealand, Mount Kilimanjaro, the Cascade Mountains (USA), etc.
- Investigate glaciers: their movement, their effect on the landscape and the features created.

Solutions to student activity

Changes in the Athabasca Glacier

The width and length of the glacier can be reliably established from the georeferenced images. Students will need to make a reasonable estimate of ice depth. One solution would be to take the valley depth from the base map and the proportion of the valley filled with ice from the 1975 photo. Alternatively, the ice thickness where the glacier ends can be assumed to be zero, and the thickness along the length estimated on the elevation profile that runs the length of the valley. Note that the elevation model is the land surface, not the ice surface.

Changes in the Athabasca Glacier

The Athabasca Glacier is located in Jasper National Park, Alberta. It is just one of many glaciers fed by the Columbia Icefield, the largest icefield in the Canadian Rockies. Meltwater from the Columbia Icefield flows into three major Canadian river systems: the Athabasca River, North Saskatchewan River and the Columbia River. The water coming from the Columbia Icefield is subject to many demands, from both human and natural sources. Some examples include: wildlife, hydroelectric generation, fishing, irrigation, aboriginal rights and trans-boundary rights. As a result, it is of great importance to understand the water reserves within the icefield and any changes to those reserves, both in the past and what may be anticipated in the future.

Task

Estimate the change in ice volume of the Athabasca Glacier between 1949 and 2009, by:

1. Identifying any estimates or assumptions you need to make, and giving your justification.
2. Explaining your method.
3. Showing your calculations and results.
4. Commenting on your results in terms of validity, limitations, and additional data that would be useful to obtain.

Data

Base map – flat image

1975 photograph

Georeferenced images (same scale and location):

Base map - 3D image

Elevation profile

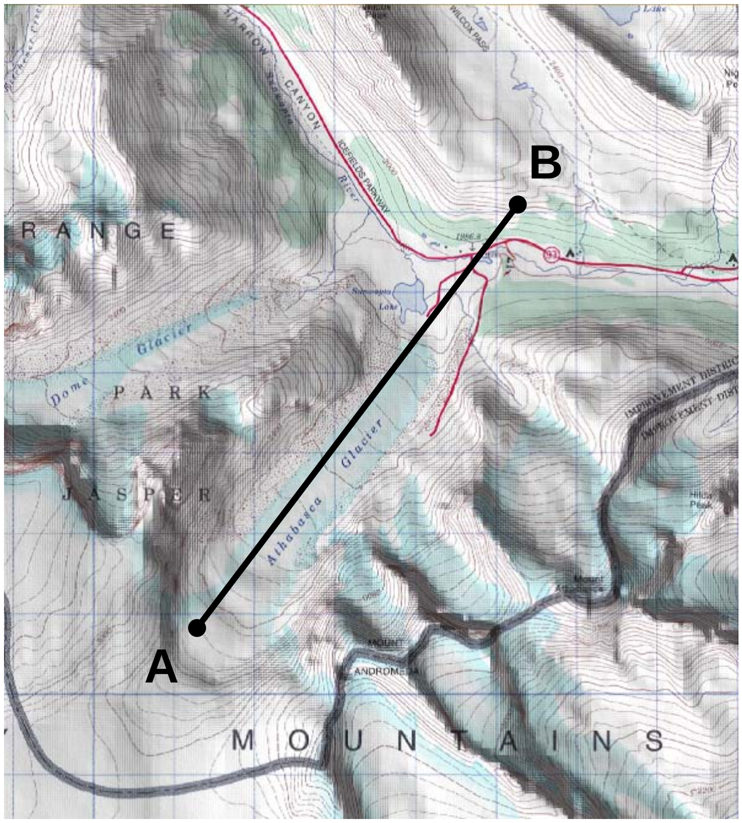
1949 aerial photograph (end of glacier located with dashed line)

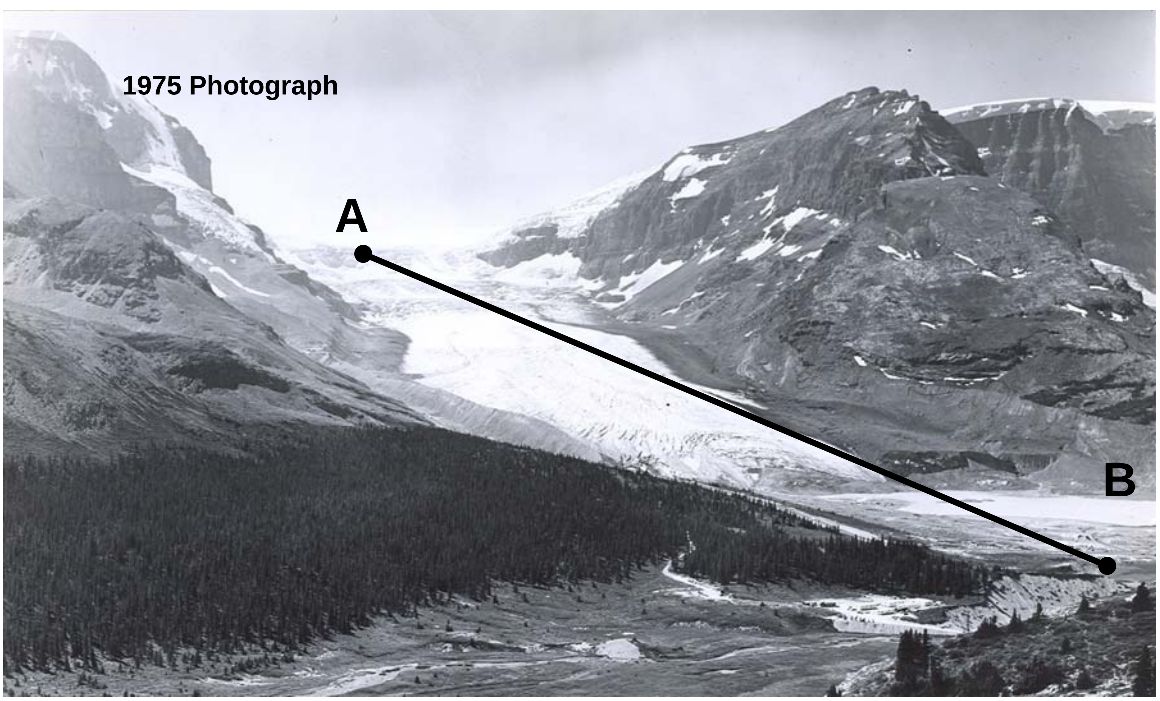
2009 satellite image (ice is coloured blue)

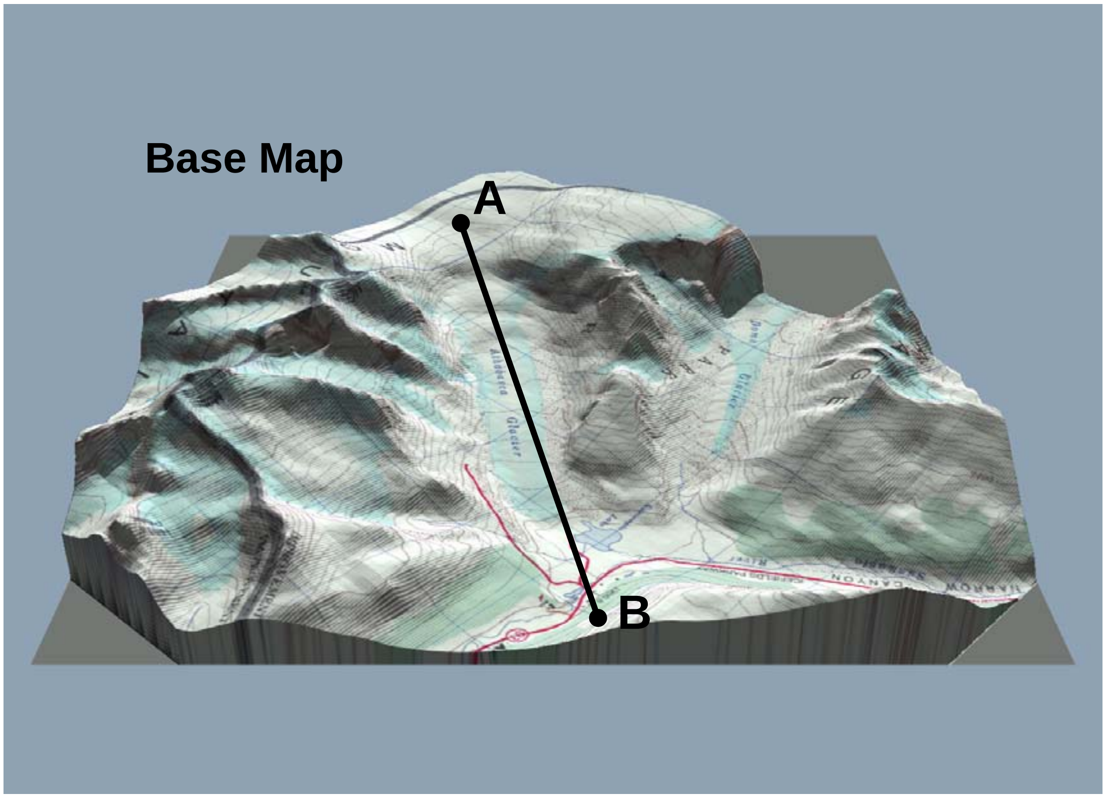
Note: the elevation profile and terrain in the 3D images are from a 2005 digital elevation model of the area.

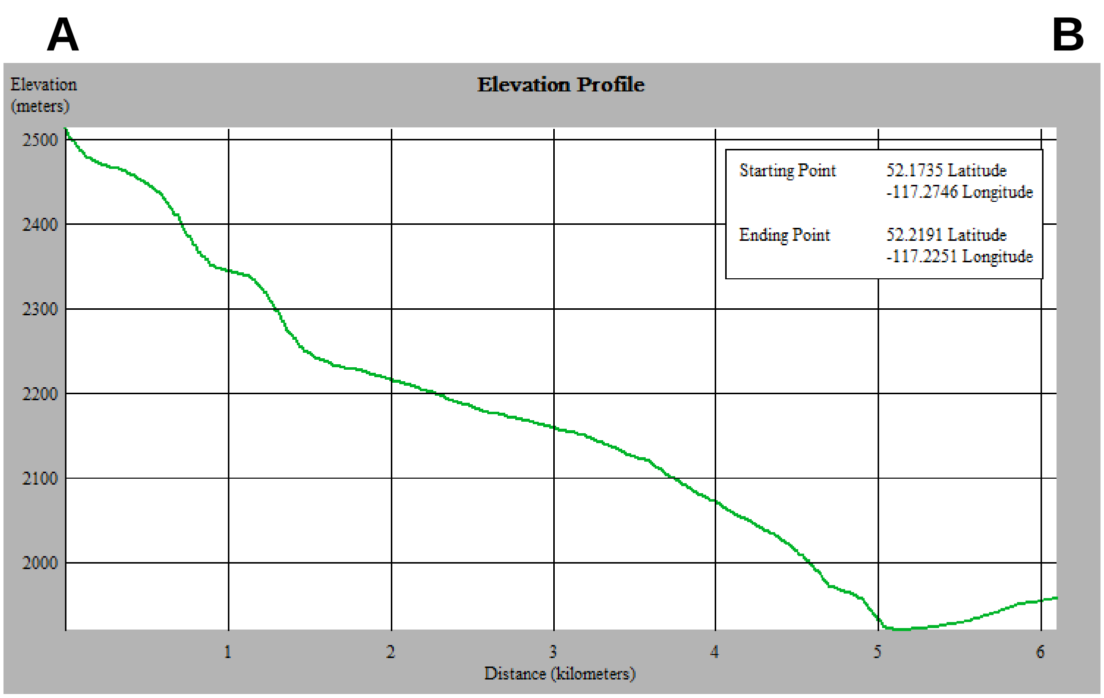
All data and images are from the Geological Survey of Canada, Natural Resources Canada.

Base Map and Elevation Profile Location



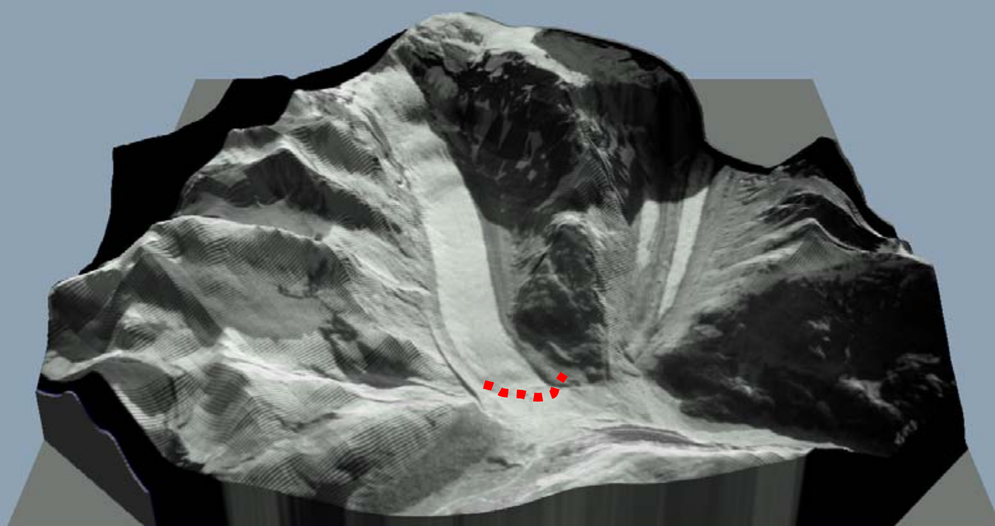



Base Map
A
B


A
B
Elevation Profile
Elevation (meters)
2500
2400
2300
2200
2100
2000
Starting Point 52.1735 Latitude -117.2746 Longitude
Ending Point 52.2191 Latitude -117.2251 Longitude
1
2
3
4
5
6
Distance (kilometers)

1949 aerial photograph

(end of glacier located with dashed line)



2009 satellite image

(ice is coloured blue)