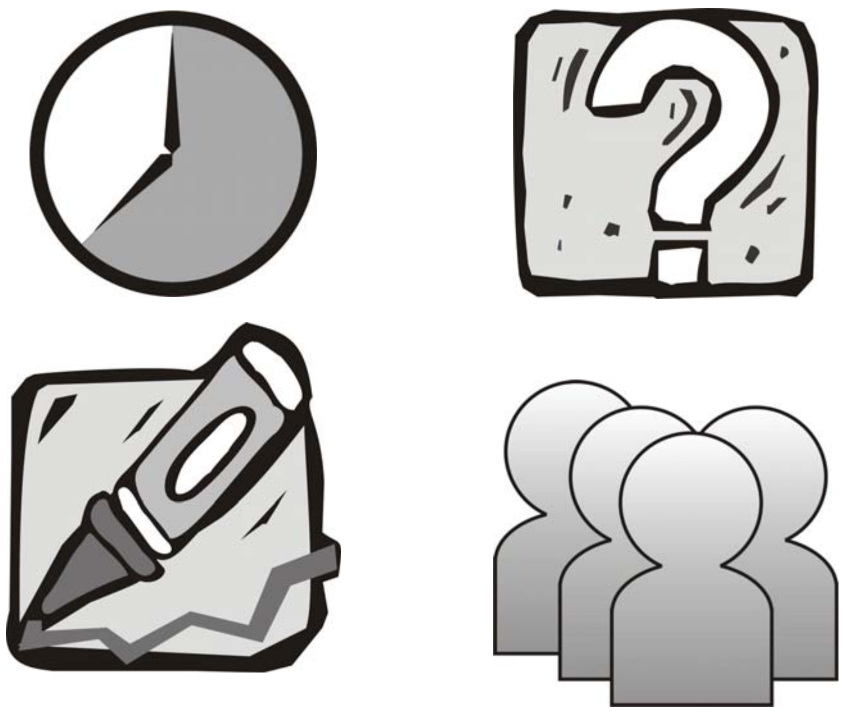
Dancing Elephants and Floating Continents

Teachers' Companion Material



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Lithoprobe Report Number 87, 2004

LITHOPROBE
Canada's National Geoscience Project
Le projet pancanadien en sciences de la Terre

Contents

Introduction

"Dancing Elephants and Floating Continents, The Story of Canada Beneath your Feet" is a landmark book for students in Canada. Published in 2003 by Key Porter Books, author John Wilson tells two stories: the geological history of our country, coast to coast, and the technological triumphs of one of the largest and longest running Canadian earth science research projects, called Lithoprobe.

This collection of companion materials is to show teachers how "Dancing Elephants and Floating Continents" can be incorporated into a hands-on, student centred unit studying the Earth. The target audience is teachers of middle or junior high school since the scientific content and language are most suited to these levels. Teachers using the materials have easily adapted the activities for primary and secondary students.

Teaching the Activities

Using "Dancing Elephants and Floating Continents"

We assume that access is always available to a copy of "Dancing Elephants and Floating Continents." In the activities it is incorporated as a read-aloud, for direction, instruction, background information, a springboard for ideas, application of knowledge, or as a source of information. Where using the book is a fundamental part of the students' activity, it is listed as a "material."

Multiple copies will be a benefit to classroom implementation, but are not essential to complete the activities as provided.

Under CanCopy licence, you may reproduce up to 15% of a publication for educational purposes. This totals 7 pages out of the 47 in "Dancing Elephants and Floating Continents." For example, giving each student or group copies of the reference pages for the reading for information tasks could make them whole class activities.

Sequence

The numbered sequence given in this study guide broadly represents a conceptual order of earth science content. "Dancing Elephants and Floating Continents" uses a historical and geographical sequence for the same concepts. You may choose to use either the numerical activity sequence in the teachers' guide, or the page number sequence in the book, whichever best suits your students and course outline. There are occasional references to previous activities, and task 15 "Shaping Our Earth" summarizes content from all the activities and naturally comes at the end of the materials. Otherwise the sequence is, to some extent, flexible.

Assessment

"Shaping Our Earth" may be used as a formal cumulative assessment and an example evaluation rubric is provided in the teachers' pages of activity15. The remaining tasks are considered learning activities and therefore no formal assessment tools are provided. However, all activities include sample student responses in the teachers' pages, and these may be used as measures of achievement for you to develop your own assessment tools and evaluation criteria.

Curriculum Content

The chart titled "Science Curriculum Connections Across Canada" documents the connections to middle school science. Some activities cover concepts that are also present in primary or secondary school curricula, but the reading level or task content would not be appropriate for these students. The chart does not include skills or knowledge covered in other subject areas on the chart, for example mathematics or language.

In most instances a significant amount (greater than 70%) of the stated course and/or strand is covered by the "Dancing Elephants and Floating Continents" activities. The companion materials are not intended, however, to provide a complete course of study for any of the Provinces and Territories, and it is assumed that teachers will refer to local curricula, and supplement activities as required.

Supplementary Resources

Where supplementary earth science materials are required for student research and additional information, online electronic resources are highly recommend. Individual activities provide links where appropriate. A keyword search will bring up many sources from professional and academic institutions around the world. Two worthy starting points that include all topics covered in this study guide (and much more) would be:

Natural Resources Canada, Earth Science Sector, Geological Survey of Canada

http://www.nrcan.gc.ca/gsc/education_e.html

> Primary sources of information on NRCan “educational sites” with Canadian content
>
> Materials available, some free, also purchase and loan (videos, posters, books)
>
> Secondary information sources, educational links to other organizations

United States Geological Survey, Learning Web

http://www.usgs.gov/education/

> Portal to an immense quantity of educational resources produced by USGS and associated organisations. Pages are searchable by topic, keyword, and type of resource with access suitable for both teachers and students.
>
> Includes electronic copies of USGS publications, which are printable and make excellent “mini textbooks.”

For print materials, any middle school text containing chapters on earth science.

Earth science texts marketed to upper middle/secondary students are very useful as reference material, for both you and the students.

Timing

Timing estimates are given on the summary chart and in each activity as relative rather than absolute values. In your classroom the actual time will depend upon many variables.

Logo	Relative Time	Typical Characteristics
	Short	Single task activities, requiring few resources.
	Medium	Activities require class time for investigation or response.
	Long	Multi-stage investigations or those requiring extensive student research.

Grouping

The summary chart and teachers' pages indicate the grouping of students for each activity.

Logo	Grouping	Typical Characteristics
	Individual	Requires personal reflection, unique product
or	Pairs or small groups	Task needs more than one person to complete all roles, equipment resources need to be shared
	Whole class	Demonstrations by the teacher, simulations requiring large numbers of people

Materials

The materials list on the teacher's pages gives everything required to complete the activity as described with a class. Items in parentheses are optional, usually relating to modifications suggested in the lesson outline.

On the student's pages, the material list is for one person or group to complete the activity. It does not include optional items.

Reproducible: reusable resource, used for the whole group, teacher presentation

Student Pages: Each student or group needs copies to complete the activity, contains instructions, recording charts, questions

Summary of Activities

	Lesson	Type	Book Connections	Theme/Concepts	Grouping	Time
1	Eggshell Earth	Data map	18, 19	Earthquakes and volcanoes around world: plate boundaries		
2	What Goes Up …	Demonstration	21, 29, 30, 42	Convection driving plate motion		
3	Cracking Up	Experiment	24, 25, 26, 27, 16, 17	Rifting and types of faults		
4	The Big One	Demonstration	14, 15, 17	Subduction at plate boundaries		
5	Shaking Canada	Data graph	12, 13	Frequency and magnitude of earthquakes in Canada		
6	Dancing on the World	Experiment	6, 7	Method of seismic exploration		
7	Visitors from Space	Experiment	38, 39	Crater properties		
8	Moving Minerals	Experiment and research	40, 41	Mineral deposits from groundwater; natural resources in Canada		
9	Happy Birthday	Data graph	43	Method of isotope dating		
10	Millions of Years	Data timescale	10, 11	Earth history timeline	and	
11	Supercontinent	Cooperative reading strategy	28, 29, 42, 43	Cyclical process of continent formation and break-up in the Earth's crust		
12	Trip of a Lifetime	Visualization	All	Canada through time		
13	Vanishing Mountains	Experiment	32, 33, 37	Erosion by water		
14	Mountain Roots	Experiment	34, 35	Isostasy: the crust is thicker under mountains		
15	Shaping our Earth	Cumulative task	All	Earth science processes that shape the Earth's surface		

Science Curriculum Connections Across Canada

Activities have been correlated to specific learning outcomes or expectations where available, otherwise to strands in the science curriculum. This does not include skills and knowledge covered in other subject areas, for example, mathematics or language.

Activities 1 - 8

Province or Territory	Eggshell Earth	What Goes Up …	Cracking Up	Big One	Shaking Canada	Dancing on the World	Visitors from Space	Moving Minerals
Alberta Grade 7 Unit E: Planet Earth	1	3	3	3		1		2
British Columbia (and Yukon)	Grade 7 Earth and Space Science: The Earth's Crust Grade 8 Earth and Space Science: Geological Processes							
Manitoba Grade 7 Cluster 4 Earth's Crust	7.4.02 7.4.13 7.4.14	7.4.02 7.4.14	7.4.13 7.4.14	7.4.02 7.4.05 7.4.14		7.4.15		7.4.03 7.4.07 7.4.14
Newfoundland and Labrador	*Grade 7 Science: Changing Land – limited connections* *Grade 8 Science: The Earth's Crust – limited connections*							
North West Territories and Nunavut	Grade 7 – 9 Science Strand: Earth, Space and Time Theme 7: Forces that Shape Our Earth Theme 8: Movement in the Earth's Crust							
Nova Scotia, New Brunswick, Prince Edward Island Atlantic Canada Science Curriculum Grade 7 Earth's Crust	110.4 209.4 210.6 311.4 311.5	311.1	311.1	311.1	209.4 311.4 311.5	109.7 111.2 112.12 209.1 211.3	209.1 209.6	112.12
Ontario Grade 7 The Earth's Crust	7s105 7s113 7s116 7s118 7s119 7s121	7s104 7s105 7s113 7s116	7s104 7s105 7s110 7s113 7s115 7s116	7s104 7s105 7s110 7s113 7s115 7s116	7s118 7s119 7s121	7s129 7s130	7s104 7s105 7s106	7s104 7s108 7s110 7s125
Quebec	Elementary Science Cycle 3: Earth and Space Systems and interactions Appropriate language Techniques and instrumentation Matter							
Saskatchewan Science 6 Earthquakes and Volcanoes	1.3 2.1 2.3 3.1 4.2	1.1 3.2	3.2 3.3	1.1 2.1 3.2 3.3	1.3 4.1 4.2	5.1		
Saskatchewan Science 8 The Moving Crust	2.1 2.2 4.2	1.3	2.1 2.2	2.1 2.2		5.1		

Science Curriculum Connections across Canada

Activities 9 - 15

Province or Territory		Happy Birthday	Millions of Years	Supercontinent	Trip of a Lifetime	Vanishing Mountains	Mountain Roots	Shaping our Earth
Alberta Grade 7 Unit E: Planet Earth				3		2 3	3	3
British Columbia (and Yukon)		Grade 7 Earth and Space Science: The Earth's Crust Grade 8 Earth and Space Science: Geological Processes						
Manitoba Grade 7 Cluster 4 Earth's Crust				7.4.13 7.4.14		7.4.04 7.4.05		7.4.01 7.4.04 7.4.14
Newfoundland and Labrador		*Grade 7 Science: Changing Land – limited connections* *Grade 8 Science: The Earth's Crust – limited connections*						
North West Territories and Nunavut		Grade 7 – 9 Science Strand: Earth, Space and Time Theme 7: Forces that Shape Our Earth Theme 8: Movement in the Earth's Crust						
Nova Scotia, New Brunswick, Prince Edward Island Atlantic Canada Science Curriculum Grade 7 Earth's Crust		111.2 112.12 210.6	209.4 311.6	110.4 311.1	209.4	209.1 209.6 311.2	209.1 209.6 210.6	110.4 311.1
Ontario Grade 7 The Earth's Crust		7s121 7s129 7s130	7s121 7s122	7s104 7s105 7s113 7s114 7s116 7s121 7s122	7s121	7s104 7s111 7s116 7s117	7s105 7s113 7s119	7s104 7s105 7s113 7s114 7s115 7s116 7s120 7s122
Quebec		Elementary Science Cycle 3: Earth and Space Systems and interactions Appropriate language *Techniques and instrumentation* Matter						
Saskatchewan	Science 6 Earthquakes and Volcanoes			3.5 3.6 3.7 4.2				3.2 4.4
	Science 8 The Moving Crust	5.2	4.1	1.1 4.3				1.3 2.2 4.1 5.1

Concept Definitions

Being able to communicate using technical vocabulary is an important part of building scientific literacy. “Dancing Elephants and Floating Continents” and the material presented in these activities contain many terms either unique to this subject or with specific meaning in this context. It is important that students develop proficiency with this vocabulary both for understanding of the material and to demonstrate their learning.

A consistent instruction strategy using a self-developed concept definition is applied throughout the activities for terms representing key concepts and ideas presented. This strategy enables students to relate new vocabulary to their prior knowledge and experiences, using language and examples that are already familiar to the students themselves.

The first time students are exposed to a concept definition the teacher provides a model of the strategy. Complete all sections of the concept definition sheet, “thinking aloud” so students are aware of the whole process, not only what is recorded on the paper. A completed example is provided on the next page, as is a blank copy to reproduce for students.

For subsequent applications, provide opportunities for guided or collaborative practice, where students receive prompts and guidance as they apply the strategy.

After a number of successfully completed concept definitions, students may apply the strategy independently.

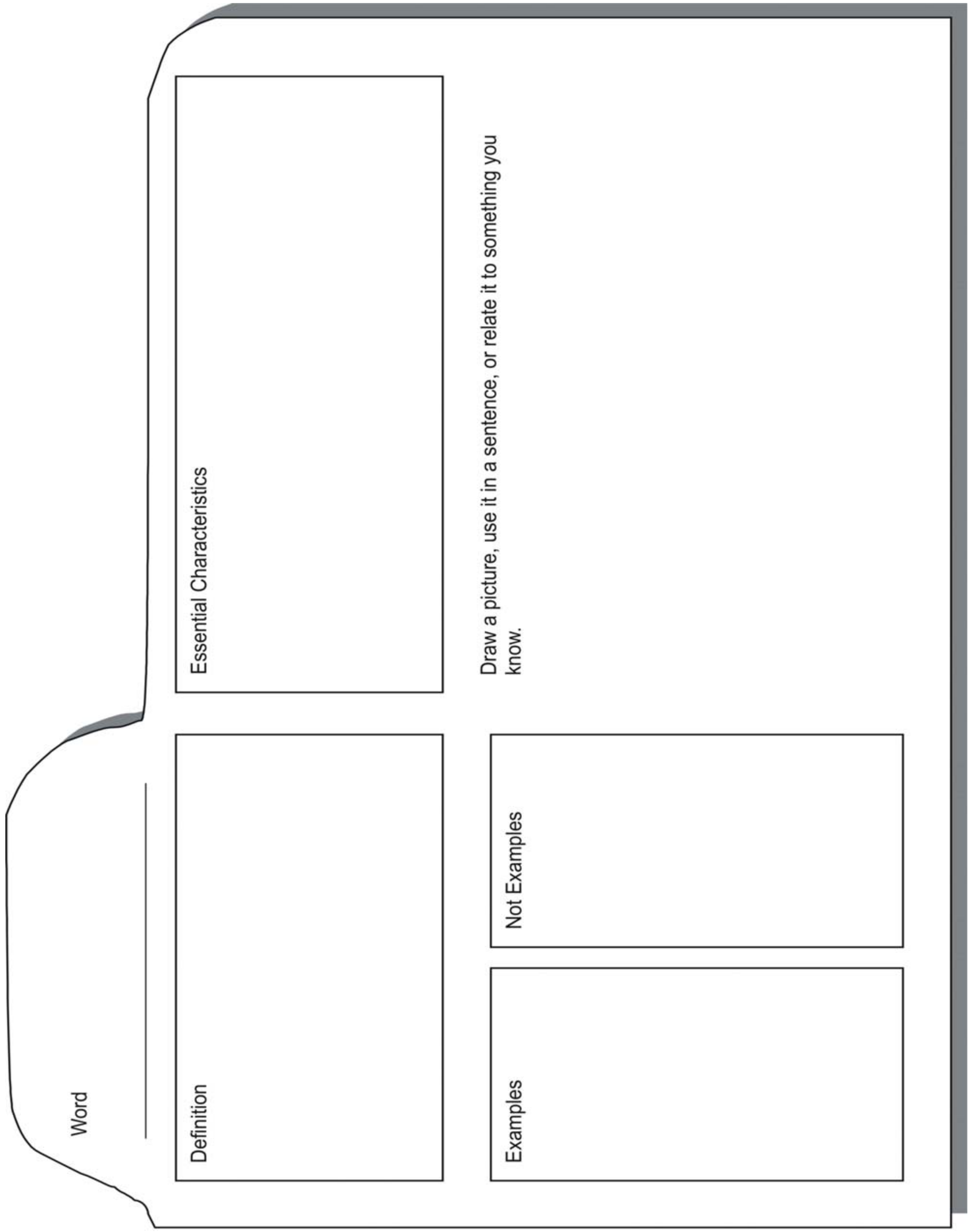
When a concept definition is included in an activity, the level of instruction or support for students is not specified. It is assumed that the teacher will modify instruction as suits each student’s experience and mastery of applying the strategy.

Key Terms in Activities Suitable for Concept Definitions

Convection
Crust
Deposition
Earthquake
Erosion
Mantle
Meteorite
Rift valley
Subduction
Supercontinent
Tectonic plates
Volcano

This list is not mandatory or exhaustive; it may be revised for each class or individual student. It is unlikely to be necessary for students to create a concept definition for every term listed as a keyword in the activities.

Concept Definition Chart



Concept Definition – Completed Example

Word

Crust

Definition

Outer layer of the Earth

Essential Characteristics

Thin

Rigid

Divided into plates

Always moving

Examples

Continents

Ocean floors

Not Examples

Mantle

Core

Water

Oceans

Draw a picture, use it in a sentence, or relate it to something you know.

It's like the skin of an apple

When cracks in the **crust** move it causes earthquakes.

Time	Grouping	Keywords	Book Connections	Activity
		Earthquake Epicentre Tectonic Plates Crust Volcano	Pages 18 and 19	

Eggshell Earth

Main Theme

Earthquakes and volcanoes occur in distinct bands on the Earth's surface. The bands show how the Earth's crust is divided into separate parts, known as tectonic plates.

Students' Tasks

Collect and map data on earthquake and volcano locations around the world from online resources.

Materials

Computer with Internet access
World outline map
Tectonic Plates of the Earth's Crust
"Dancing Elephants and Floating Continents"

Health and Safety

There are no experimental safety issues in this activity. Research is required using the Internet and suitable measures need to be in place to "net proof" students.

Lesson Outline

Background

The outer layer of the Earth, the crust, is broken into interlocking plates, like a cracked eggshell. Most plates contain regions of both oceanic and continental crust, which differ in rock type and thickness. Zones of earthquakes and volcanoes tend to coincide with the boundaries between these plates.

Constructive plate margins are where the plates move apart and new crust is created. Many shallow earthquakes happen in these areas, e.g. the Mid Atlantic Ridge. If curst is created, it must also be destroyed, which happens through "subduction" (see "The Big One") at destructive plate margins where plates are colliding. One plate sliding under the other causes numerous earthquakes that can be of great magnitude and depth.

Subduction zones are also the locations of major activity, often explosive and unpredictable. The subducting plate melts at great depth and magma rises up through the plate above to the surface.

Preparation There are many sources of data online about earthquake occurrences and volcanic activity around the world. Any would provide the information to create maps of the locations. As an independent research task, this is perhaps not suitable for middle school students since the quantity of data may be overwhelming. Using a spreadsheet plotting function or GIS mapping software is really necessary to complete the task with meaningful results, i.e. to see a pattern in the distribution.

Alternatively, seismic and volcanism reporting institutions create their own maps using pre-sorted data. Currently one of the best earthquake packages for this task can be found from the Incorporated Research Institutions for Seismology Consortium (IRIS) on their website

http://www.iris.edu/quakes/maps.htm

IRIS provides maps and lists of earthquakes occurring worldwide in the previous day, week, month and year. The "event search" function is a simple interface where students may create their own maps for specified time period, geographic area, magnitude or depth ranges. "SeismiQuery" is more suitable for users with specialist knowledge or needs.

The Global Volcanism Program (GVP) from the Smithsonian National Museum of Natural History provides data suitable for the volcanic mapping task. Every volcano known to have been active in roughly the last 10, 000 years is plotted on the main global map found at:

http://www.volcano.si.edu/world/location.cfm

There is a wealth of other information on the GVP site. Especially useful are the "frequently asked questions" from the main page http://www.volcano.si.edu that include "how many active volcanoes are there in the world?" The language used is for competent readers, but the site does not require specialized knowledge for understanding.

Additional information about volcanoes is found at Volcano World, designed for people of all ages: http://volcano.und.novak.edu. The website includes children's and teachers' areas, facts, models, activities, images and much more.

This activity is complemented by "Shaking Canada" which looks more closely at Canadian earthquakes.

Activity Provide students with access to the websites listed, a blank world outline map, and the students' page. The students use data collected from the Internet to identify zones of the world most prone to earthquakes and volcanoes on their outline maps. They analyze the pattern of earthquake and volcano distribution and make suggestions for the cause.

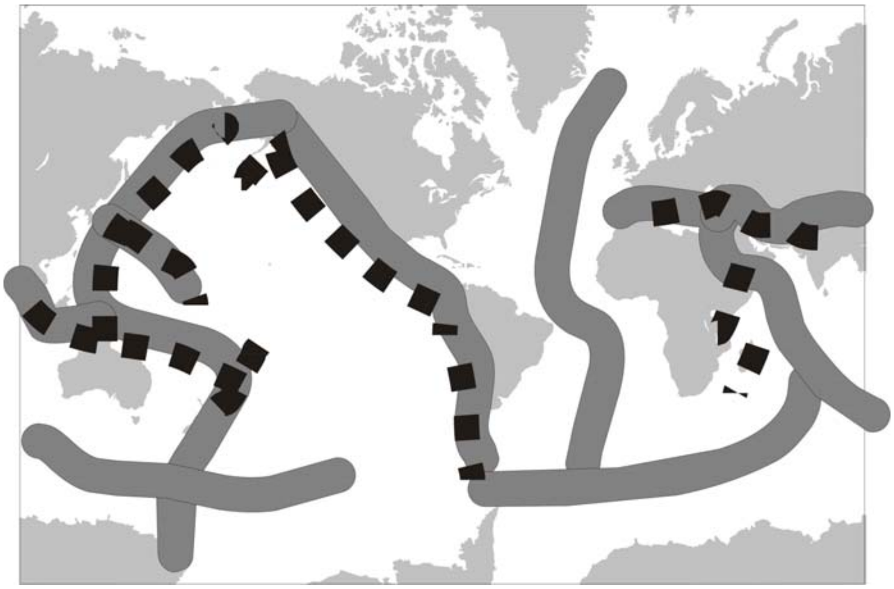
Close Either: teacher-led discussion using the map showing the "Tectonic Plates of the Earth's Crust" (see reproducible). Read aloud the text box on page 19 of "Dancing Elephants and Floating Continents" about "Plate Tectonics." Compare the tectonic boundaries to the students' map of earthquakes and volcanoes.

Or: Students read the text box on page 19 of "Dancing Elephants and Floating Continents" about "Plate Tectonics" and compare the tectonic boundaries to areas of earthquakes and volcanoes on their map.

Sample Student Responses

Sample Student Map

Solid lines = earthquake zones, Dashed lines = volcano zones



Do earthquakes and volcanoes occur everywhere on the Earth's crust? *No*

Do earthquakes occur everywhere we find volcanoes? *Yes*

Do we find volcanoes everywhere that has earthquakes? *No*

Describe the patterns you see formed where earthquakes and volcanoes occur. *We see both in a ring around the Pacific Ocean, the west coast of North and South America, and a line separating Europe and Asia from Africa and India. We also see earthquakes down the middle of the Atlantic Ocean, around the rim of Antarctica, and up through the Indian Ocean.*

What do you suppose the patterns that you see tell us about the Earth's crust?

Various responses are possible: there are cracks in the crust, that some parts are stronger than others.

Read the text box titled "Plate Tectonics" on page 19 of "Dancing Elephants and Floating Continents". Look carefully at the map showing the plates. What do you notice when you compare the plate boundaries to the zones of earthquakes and volcanoes on your map?

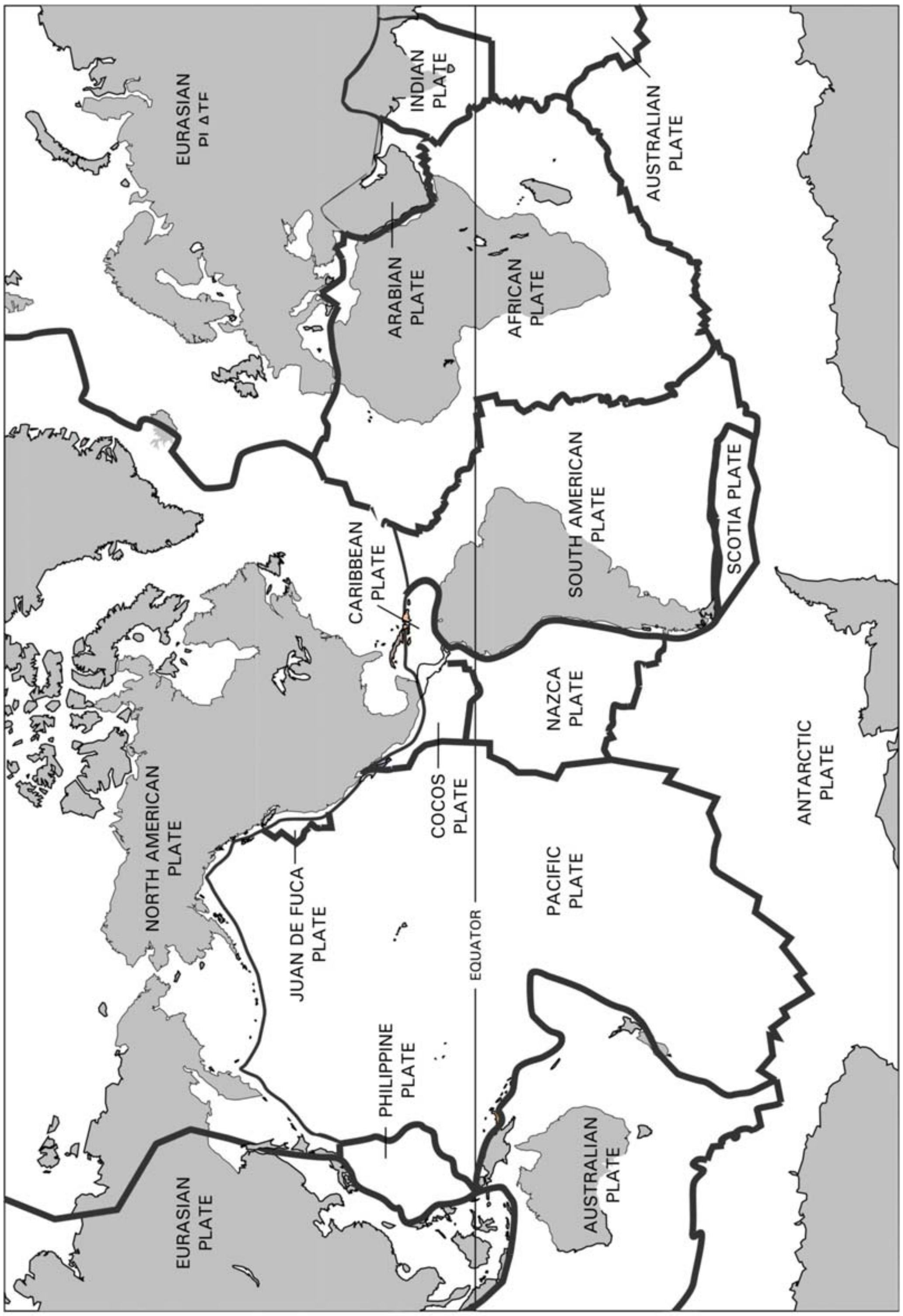
All the earthquake and volcano zones line up with plate boundaries. Some of the plate boundaries have volcanoes and earthquakes, some have only earthquakes, and some boundaries have neither.

How would you feel moving from an area where there are few volcanoes and earthquakes, like central Canada, to a place where they occur more often, like western Canada?

Personal reflection from students.

Tectonic Plates of the Earth's Crust

Modified from "This Dynamic Earth: The Story of Plate Tectonics," USGS 1996



World Outline Map

Eggshell Earth

Where do earthquakes and volcanoes happen?

Materials

Computer with Internet access

World outline map

“Dancing Elephants and Floating Continents”

Keywords

Earthquake
Epicentre
Tectonic Plates
Crust
Volcano

Book Connections

Pages 18 and 19

Safety When using the Internet, never give out any personal information. Use the websites recommended in the activity.

Instructions

Use the information available online to colour areas on your world map where earthquakes regularly occur and where volcanoes are found.

Use different colours and/or symbols to show the two zones.

Earthquake information can be found at Incorporated Research Institutions for Seismology Consortium (IRIS): http://www.iris.edu/quakes/maps.htm

Volcano information can be found at Global Volcanism Program, Smithsonian National Museum of Natural History: http://www.volcano.si.edu/world/location.cfm

When your map is finished, use the time available to browse the other information about earthquakes and volcanoes on these two websites.

Analysis

Do earthquakes and volcanoes occur everywhere on the Earth's crust? ____________

Do earthquakes occur everywhere we find volcanoes? ____________

Do we find volcanoes everywhere that has earthquakes? ____________

Describe the patterns you see formed where earthquakes and volcanoes occur.

What do you suppose the patterns that you see tell us about the Earth's crust?

Read the text box titled "Plate Tectonics" on page 19 of "Dancing Elephants and Floating Continents". Look carefully at the map showing the plates. What do you notice when you compare the plate boundaries to the zones of earthquakes and volcanoes on your map?

How would you feel moving from an area where there are few volcanoes and earthquakes, like central Canada, to a place where they occur more often, like western Canada?

Time	Grouping	Keywords	Book Connections	Activity
		Mantle Crust Convection Density Tectonic Plates	Pages 21, 29, 30, and 42	

What Goes Up …

Main Theme

Plate motion is driven partly by convection currents in the mantle.

Students' Tasks

Relate a demonstration to convection in the Earth.

Materials

Large transparent container (e.g. aquarium, large glass jar)
Hot water
Cold water
Small container with lid
Food colouring
(Lava Lamp)
Structure of Earth overhead (see reproducible)
Convection in Earth overhead (see reproducible)
Overhead projector
Concept Definition chart
"Dancing Elephants and Floating Continents"

Health and Safety

Water spills must be cleaned up immediately.

Lesson Outline

Background

The question of how the plates could move was a major stumbling block to the scientific community accepting the theory of tectonic plates. It is still an area of debate and ongoing research. That convection occurs is not questioned, but the patterns within the Earth are not well understood, nor how convection may have started. An ongoing question is whether convection is the cause or effect of plate motion. Other processes that may contribute to fuelling plate motion include ridge-push, slab-pull, and trench-suction. These relate to the physical properties of the plates such as temperature and density, and their different behaviour due to gravity caused by variations in these physical properties.

Preparation

Set up a large transparent container filled with cold water in a place that can be seen easily by the whole group.

Depending on the prior knowledge of your students, the explanation of convection can be expanded to refer to temperature induced density differences. Cold water is denser than hot water therefore hot water rises and cold sinks.

Providing the keyword list in advance, and having students record how each keyword is important to the topic can differentiate the listening sheet activity.

Activity Distribute listening sheets to students. Follow the demonstration script, carrying out the instructions as described.

Close Students write a summary passage on their listening sheets.

Complete a concept definition chart for “convection.”

Sample Student Responses

Listening sheet: *Students individual responses*

Concept Definition for “convection”:

Definition: *currents and movement (in liquids) between hot and cold places*

Essential Characteristics: *hot things rise, cold things sink; needs differences in temperature; makes things move*

Examples: *tectonic plates moving; water in the tank; convection stoves; lava lamp*

Not examples: *microwave oven; earthquakes*

Draw a picture, use it in a sentence, or relate it to something you know: *convection hot air heaters take in cold air at the bottom, heat it, and put out hot air at the top.*

Demonstration Script

Teacher: I am going to show you something very important about our Earth. As you watch and listen, fill in the box on your listening sheet with any keywords or ideas that you think are important. We've seen that the Earth's crust is divided into separate regions called tectonic plates. What happens as those plates move around and rub up against each other?

Students: Earthquakes and volcanoes

Teacher: In the story about Lithoprobe's Dancing Elephants and Floating Continents we've heard and read lots about mysterious forces pushing, pulling the crust, closing oceans, building mountains and more.

Now let's see what earth scientists think is making those plates move.

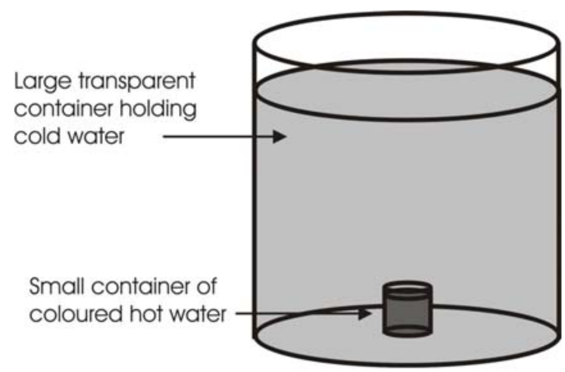
[Instruction: Fill the small container with hot water, add a few drops of food colouring, and put on the lid.]

Teacher: I've filled this big container with cold water, and in this little one is hot water. Now I'll add some food colouring to the hot water – so we can tell it apart from the cold water.

What do you think will happen if I put the jar of hot water in the bottom of the cold water?

Students: Various responses possible, accept any prediction.

[Instruction: Put on the lid and place the container of hot water at the bottom of the large cold water tank. Quickly take the lid off and remove your hand.]



Teacher: Can you see how the hot water moves? Watch what happens when it reaches the surface.

Students: The hot water rises up and once it reaches the top it moves out sideways under the water surface

Teacher: This is called "convection" and it's the same idea used in convection heaters. Just like the hot water, hot air rises, so convection heaters take cold air in at the base, heat it, then the hot air is put out at the top.

What do you think would happen if I put cold water in the small container?

Students: Various responses possible, accept any prediction.

Teacher: Let's see.

[Instruction: Remove and refill small container with cold water. Add food colouring and replace in the bottom of the large cold-water tank.]

Students: It doesn't rise up this time

Teacher: For convection to work, there needs to be differences in temperature. Hot water rises through cold water.

So what does this tell us about the moving plates in the Earth's crust? Look at this diagram showing the inside of the Earth.

[Instruction: Display “Structure of Earth” overhead.]

Where is the hottest part of the Earth?

Students: The centre, the core.

Teacher: The mantle must be hotter at the bottom because it’s closer to the centre of the Earth, and cooler at the top just below the crust. Because of this, we get convection in the mantle, just like we saw with hot and cold water in the tank. The mantle isn’t liquid, but because of the tremendous heat and pressure inside the Earth, it is able to flow. This happens in enormous circles throughout the mantle.

[Instruction: Show Convection in the Earth overhead and point out the motion.]

Teacher: From the hotter parts just above the core, the warmer rock rises up, cools again once it reaches the crust, then the cooler rock moves down in these giant circles or convection currents.

With all this movement, what do you think might happen to the crust on top of the mantle?

Students: It is moved, it sinks too.

Teacher: The crust is more rigid than the mantle, but they are attached, so as convection moves the mantle around, the plates in the crust get dragged along too. Where the hot mantle rises, the plates are pulled apart, which causes what?

Students: Rifting and ocean forming.

Teacher: And where the plates collide and the cooler mantle sinks, what do we see?

Students: Subduction

Teacher: So, convection is the engine that provides the forces moving the continents, making mountains, causing earthquakes and volcanoes.

Optional, if lava lamp available:

Teacher: We can also see convection at work in a Lava Lamp. What can you see when it’s turned off?

Students: Bubbles at base

Teacher: Watch as we turn it on. What happens?

[Instruction: Turn on the lamp.]

Students: Bubbles start to rise and fall

Teacher: Which is the hottest part of the lamp?

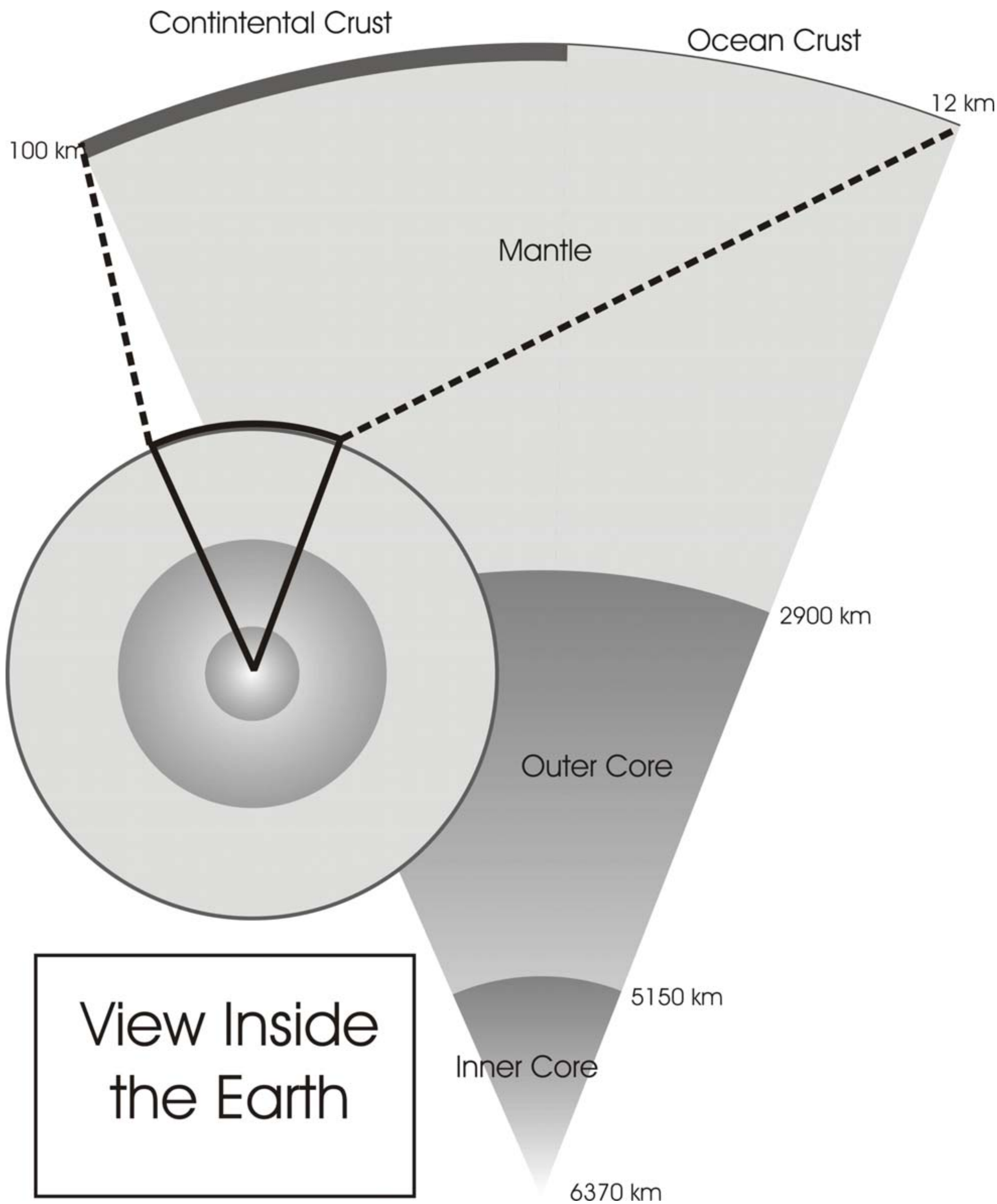
Students: Where the bulb is in the base.

Teacher: So what’s happening to the temperature of the bubbles as they move?

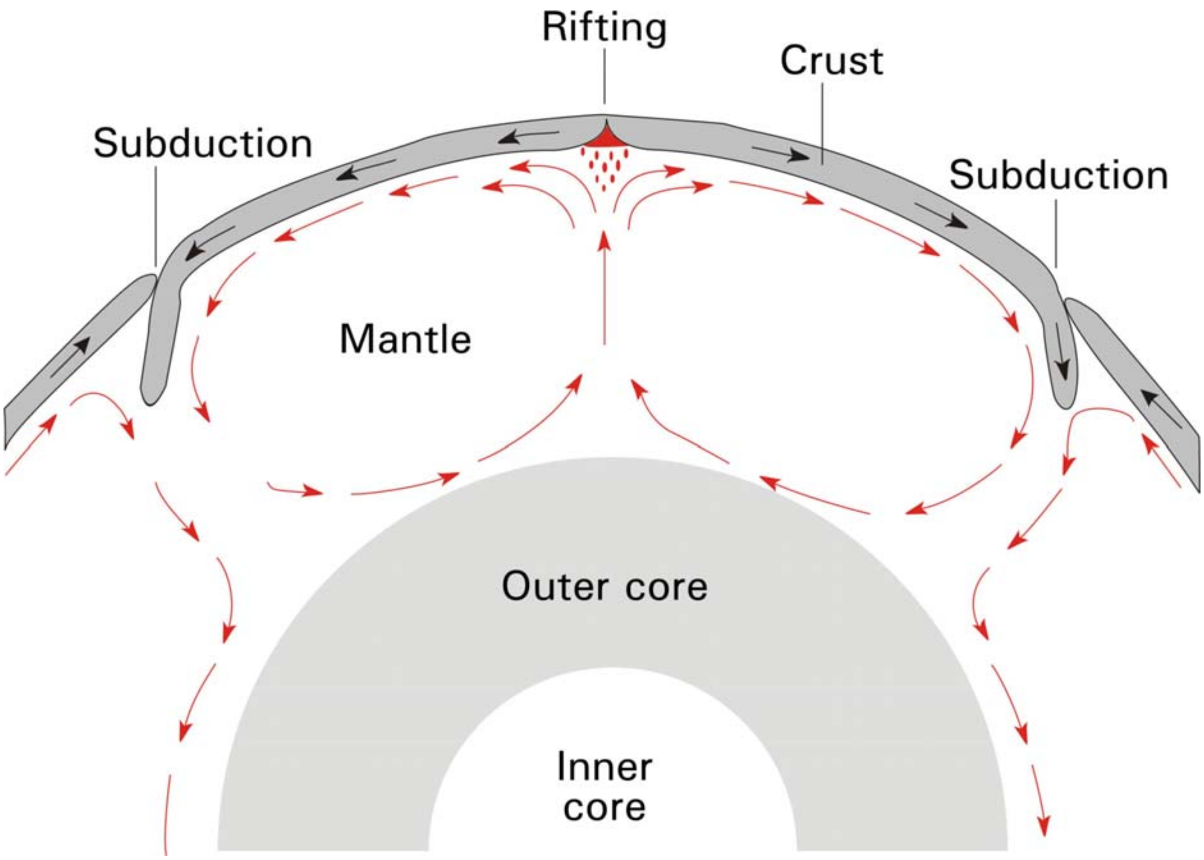
Students: Hotter at base, cooler as they move away from it.

Teacher: As the bubbles warm up they rise up the lamp, and sink again as they cool down. This is just like convection in the water, and in the mantle.

Structure of the Earth (Approximately to scale)



Convection in the Earth



Modified from “This Dynamic Earth: The Story of Plate Tectonics,” USGS 1996

What Goes Up …

How do the tectonic plates move?

Materials

Concept definition chart

Keywords

Mantle
Crust
Convection
Density
Tectonic Plates

Book Connections

Pages 21, 29, 30, and 42

Safety There are no safety issues in this activity.

What Goes Up: Listening Sheet

As you listen and watch the demonstration, note down what you think might be keywords and ideas below.

When the demonstration is finished, look over your notes and highlight the words or ideas that are most important.

Write a summary of the main topic of the demonstration in the space below.

Time	Grouping	Keywords	Book Connections	Activity
		Rift valley Fault Normal Thrust Strike slip Force Crust Mantle	Pages 24, 25, 26, 27 (16 and 17)	

Cracking Up

Main Theme

Forces within the Earth's crust cause cracks, or "faults." Rift valleys are where the crust is being pulled apart, and deep valleys form where the crust faults and slumps downwards.

Students' Tasks

Investigate how rift valleys are formed and compare the main types of faults using models and research.

Materials

"Dancing Elephants and Floating Continents"
Modelling clay
Fault block model (see lesson outline)
Concept definition chart
Supplementary reference material (see lesson outline)

Health and Safety

Students are to wash their hands after using modelling clay.

Lesson Outline

Background See descriptions in the sample student responses.

Preparation In advance of the activity, prepare a block model for students to use in the investigation. Make a quadrangular block, and cut through the centre at an angle. Mark layers around the edges so that movement from the start position can be followed. See illustrations to the right and on the student page.

Styrofoam is well suited for the model; use a Styrofoam hot wire cutter in a well-ventilated space. Two small boxes such as a tissue box can be cut; the ends folded up to make the centre wall, then covered and decorated. Layers of modelling clay may be used; take care the layers do not deform when you cut it, or when students manipulate the model. Add surface features like a road or river that are continuous in the start position but that cross the fault line, so are broken when the fault moves.

Supplementary reference material will be needed for students to study the different fault types. Any mid to upper level earth science or physical geography textbook will most likely include pictures and information. Diagrams and animations of fault movement can be found in many places online. Two excellent examples are:

United States Geological Survey http://earthquake.usgs.gov/image_glossary/fault.html

IRIS Consortium http://www.iris.edu/gifs/animations/faults.htm

Activity

Provide students with all the materials and student pages. Students use modelling clay to simulate thinning and rifting due to stretching following the instructions on page 25 of "Dancing Elephants and Floating Continents". They complete a concept definition for "rift valley."

Using the fault model, "Dancing Elephants and Floating Continents" and additional resources, students find out the differences between normal faults, thrust faults and strike slip faults through a combination of experimentation and research. They complete a comparison chart to define the terms.

When students are manipulating the block model, be aware of a common misconception: faults are not holes in the ground, despite what tends to be shown in movies. The two blocks slide relative to each other, and don't create a gap between them.

Sample Student Responses

Rift valley – Concept Definition

Responses as phrased in "Dancing Elephants and Floating Continents":

Definition: *cracks in the Earths' crust as it is pulled apart*

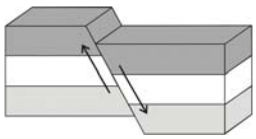
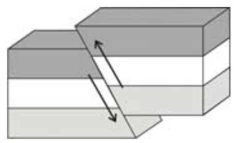
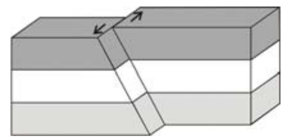
Essential characteristics: *steep walled, stretching, two faults side by side, crust between drops down, continent being pulled apart, may be flooded by ocean, lava fills up centre*

Examples: *East Africa, modelling clay, Atlantic Ocean*

Not examples: *San Andreas*

Diagram, sentence, or personal connection: *Depends on student*

Fault Type Comparison Chart

	Normal	Thrust	Strike Slip
Description	*Normal fault shows extension faulting, one block moving away from the other.*	*Thrust fault shows compression faulting, one block moving toward the other.*	*Strike Slip fault shows shear faulting, one block moving along the other sideways*
Diagram			
Which direction does the force act that creates it?	*Away from the fault* *Extension*	*Towards the fault* *Compression*	*Along the fault* *Shear*
At which kind of plate boundary is it commonly found?	*Constructive*	*Destructive or subduction*	*Transverse*
Important or interesting facts	*Depending on student research: locations, examples, magnitudes of earthquakes, frequency, etc.*		

Cracking Up

How does the Earth's crust move?

Materials

“Dancing Elephants and Floating Continents”
Modelling clay
Fault block model
Concept definition chart
Supplementary reference material

Keywords

Rift valley
Fault
Normal
Thrust
Strike slip
Force
Crust
Mantle

Book Connections

Pages 24, 25, 26, 27
(16 and 17)

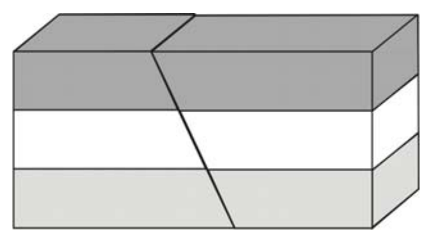
Safety Wash your hands after using modelling clay.

Instructions

Follow the instructions on page 24 and 25 of “Dancing Elephants and Floating Continents” and investigate what happens as you stretch the modelling clay.

Complete a concept definition page for “rift valley.” Pages 26 and 27 will help you.

Set up the block model in the start position as shown in the picture. Imagine the join between the two parts is a fault in a section of the Earth's crust.



Investigate the different ways you can move the two parts of the model, without making a space between them. Watch what happens to the patterns on the surfaces of the model.

Using the block model, “Dancing Elephants and Floating Continents” and any other resources provided, find out the differences between normal faults, thrust faults and strike slip faults. Complete the comparison chart to organize the results of your research.

Types of Faults Comparison Chart

	Describe in your own words	Draw a picture	Which direction does the force act that creates it?	At which kind of plate boundary is it commonly found?	Important or interesting facts
Normal					
Thrust					
Strike Slip					

Time	Grouping	Keywords	Book Connections	Activity
		Subduction Crust Collision Mantle Earthquake Volcano Tectonic plate	Pages 14, 15, and 17	

The Big One

Main Theme

Destructive plate margins are called subduction zones and are the location of many of the worlds' largest earthquakes and volcanoes, and mountain building.

Students' Tasks

Interpret a demonstration in context of plate boundaries and subduction earthquakes.

Materials

"Dancing Elephants and Floating Continents"
2 pieces of flexible foam (e.g. mattress)
Tectonic plate shape cut outs (see reproducible)
Subduction zone overhead (see reproducible)
Tectonic Plates of the Earth overhead (see "Eggshell Earth")
Overhead projector
Concept definition chart

Health and Safety

There are no safety issues in this demonstration.

Lesson Outline

Background Destructive plate margins or subduction zones are where one plate is sliding under another as they collide. The Cascadia subduction zone is located along the west coast of British Columbia, Washington and Oregon. Transverse movement of other nearby plate margins causes the common earthquakes in British Columbia. The geological evidence shows that the subduction zone causes an earthquake of magnitude greater than 7 once every 300 - 500 years. The Pachina Bay earthquake of 1700 was the last subduction earthquake in British Columbia. Lithoprobe scientists are part of a focussed effort to understand the Cascadia subduction zone and the risk of another large earthquake occurring in British Columbia.

Preparation This activity must be done after "Cracking Up" and "Eggshell Earth."

Read through the teacher's script and practise with manipulating the foam to get the desired effect.

Cut out acetate versions of the major tectonic plates (see reproducible).

Activity Teacher uses the demonstration script, reading aloud and using the materials and resources as instructed in the script. Allow time for student responses at the question prompts, guiding the discussion within the demonstration goals.

Close Complete a concept definition card for "subduction."

Additional Information Sources

"This Dynamic Earth, the Story of Plate Tectonics" published in print and online by the USGS (United States Geological Survey):

http://pubs.usgs.gov/publications/text/dynamic.html

Ideally suited as background and supplementary information for teachers, or confident independent student readers. It is well illustrated, and includes historical development of the theory, present-day observations, explanation of tectonic phenomena, and importance to humans.

Sample Student Responses

Concept definition for "subduction":

Definition: *type of plate boundary where one plate is moving downwards below another as the two plates collide*

Essential characteristics: *plates moving together; one below the other; the subducting plate heats, finally melting as it gets deeper in the mantle; large scale feature of Earth*

Examples: *Japan, Alaska, British Columbia, South America*

Not Examples: *California, rifting, spreading/ocean ridge*

Draw a picture, use it in a sentence, or relate to something you know: *Subduction causes many large earthquakes and volcanoes.*

Demonstration Script

Teacher: We have seen that the Earth’s crust is split into sections. What was the name for those sections?

Students: Tectonic plates

Teacher: The plates are constantly moving; very slowly, but with huge forces compared to anything we are used to experiencing. When the plates pull apart, the crust thins, and eventually splits. What can happen then?

Students: Rift valleys and ocean basins

Teacher: If the plates are moving apart in one place, but the surface of the Earth stays the same size, what must be happening elsewhere?

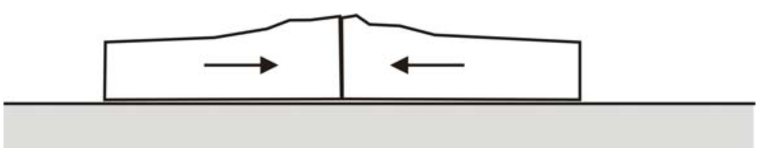
Students: The plates must be moving together.

Teacher: These are simple versions of the Earth’s plates. If I lay them all side by side, and move these two in the middle apart, watch what happens to the ones at the edges.

[Instructions: Place the “Tectonic Plate Shape” cut out pieces so that they all touch. Lightly tape the outer pieces so they cannot move. Choose 2 in the centre of the arrangement and slowly move them apart. As they push against the outer ones, they will crumple up and overlap.]

Teacher: When the plates move together like that, a number of things happen that are really important. Let’s try and imagine that these two pieces of foam are two tectonic plates.

[Instructions: Place two pieces of foam butted end to end horizontally.]



Teacher: In the Earth’s crust, the plates don’t have gaps between them. These two start off just lying side by side. What if they start moving together slightly?

[Instruction: Push evenly on both pieces of foam. Aim to have them squash and thicken equally. This is easier to achieve if the foam is on a firm surface, like a tabletop.]

Teacher: What do you see?

Students: The foam is thicker and bending upwards in the middle where they collide.

Teacher: If this were really the Earth’s crust, what do you think would be happening where the plates are thickening?

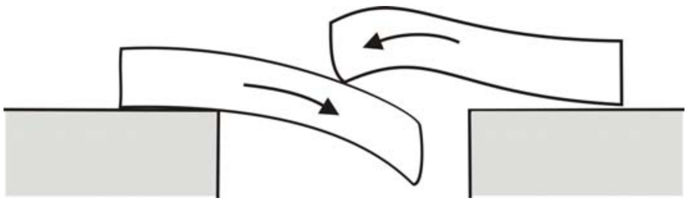
Students: Mountains would be forming.

Teacher: This is just like what is happening between India and Asia - the Himalayas are still being pushed upwards. Sometimes in this battle of colliding plates, they are not as evenly matched.

[Instructions: Separate the pieces of foam back to the starting position.]

Teacher: What can also happen as the plates collide is that one is forced down under the other.

[Instructions: Put the foam pieces across a gap between two tables or boxes. Move the foam pieces together and let one slip under the edge of the other. It’s tricky – practice first! With patience you can show a subducting plate, the ocean trench, and coastal uplift.]



Teacher: Watch how the plates change shape. What can you see?

Students: The lower one is bent downwards, the upper one is shortened, bent upwards and thicker close to the collision, there’s a dip (trench) where they meet.

Teacher: This plate that is going downwards, what do you think might happen, as it gets deeper and deeper?

Students: It gets hotter and will eventually melt.

Teacher: And what will this molten rock do?

Students: Rise to the surface as a volcano (because it is less dense)

Teacher: The special name for this type of boundary between tectonic plates is a subduction zone. When you did your map for Eggshell Earth, most of the major earthquakes and volcanoes in the world happen on subduction zones, like around Japan, South America and Alaska.

[Instruction: Show overhead of “Tectonic Plates of the Earth” and indicate the subduction zones]

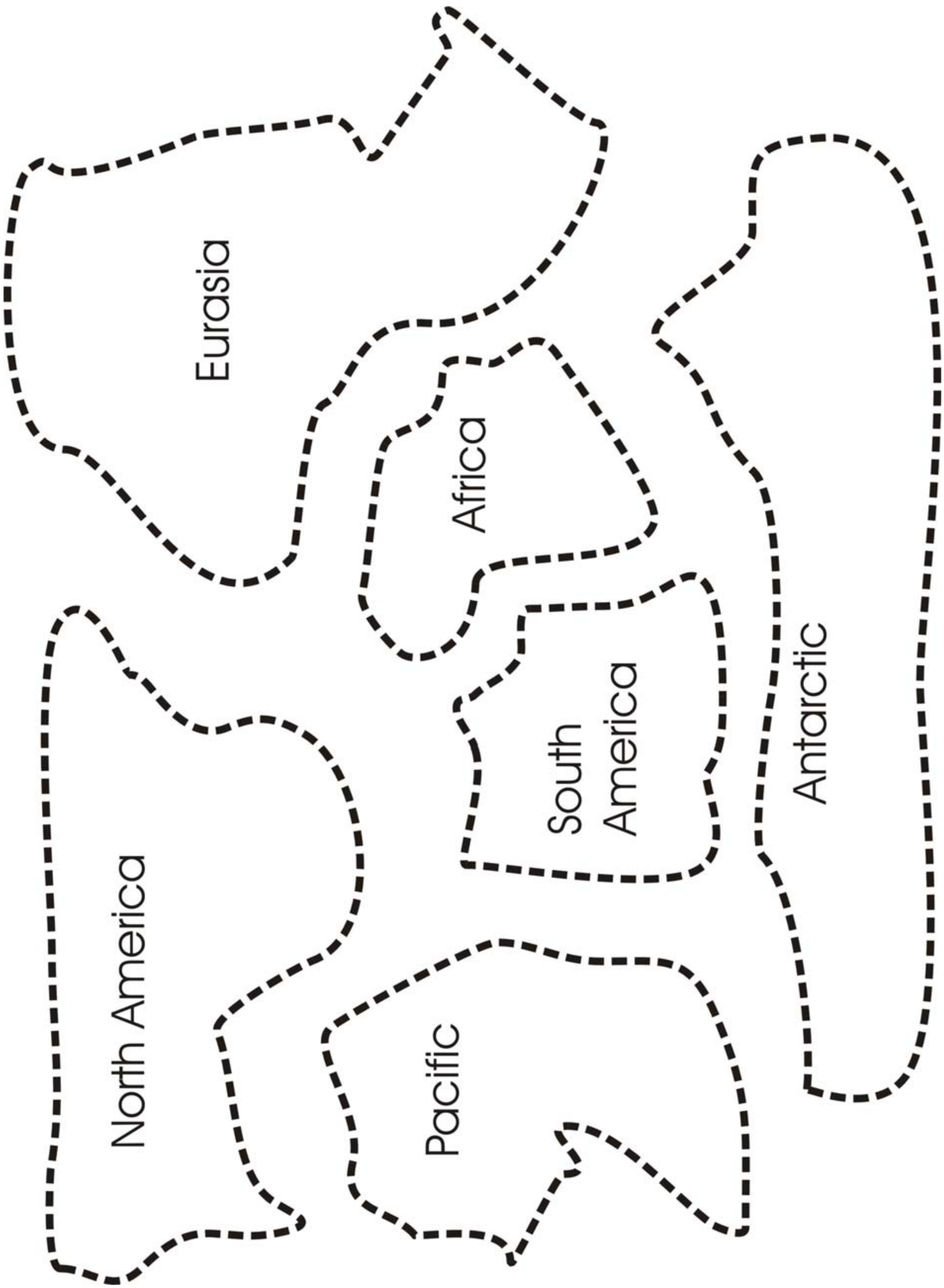
Teacher: Where the two plates are rubbing against each other, this can cause huge earthquakes, and where the plate going down melts, the molten rock rises to the surface and forms volcanoes.

[Instruction: Show overhead of “subduction zone” and indicate earthquakes and volcanoes]

These huge earthquakes don’t happen very often, but when they do they can cause great damage. We know when the last really big one happened in Canada. Let me tell you the story.

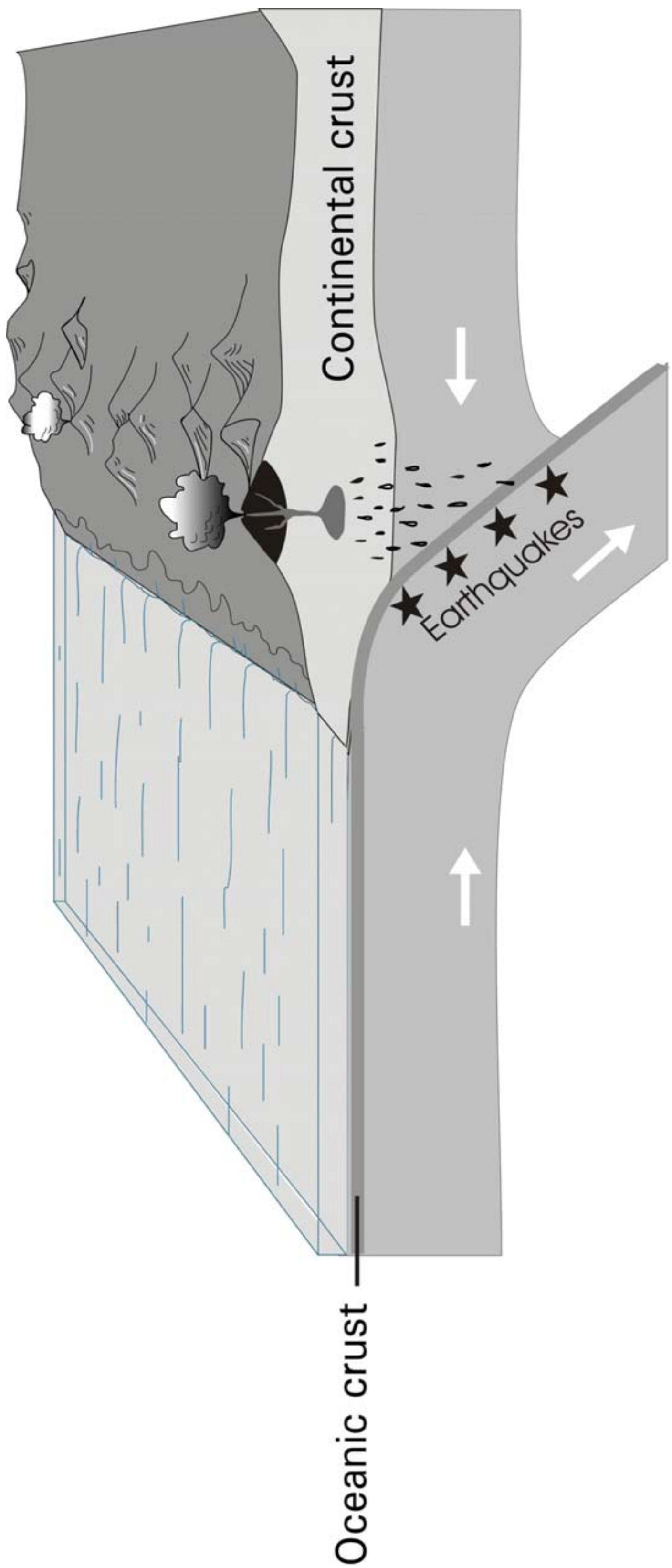
[Instruction: Read pages 14 and 15 “No One Survived”.]

Tectonic Plate Shape Cut Outs



Subduction Zone

Modified from “This Dynamic Earth: The Story of Plate Tectonics,” USGS 1996



Time	Grouping	Keywords	Book Connections	Activity
		Magnitude Earthquake	Pages 12 and 13	

Shaking Canada

Main Theme

Earthquakes occur daily in Canada, but most are hardly felt and cause no damage.

Students' Tasks

Use an earthquake reporting website to collect data and produce graphs showing the number and magnitude of earthquakes in Canada.

Materials

Computer with Internet access
Graph paper
"Dancing Elephants and Floating Continents"
(Spreadsheet software)

Health and Safety

There are no experimental safety issues in this activity. Research is required using the Internet and suitable measures need to be in place to "net proof" students.

Lesson Outline

Background

Many people do not realise how frequently earthquakes occur. Small earthquakes causing little or no damage are daily events in many places, including Canada. The majority of Canada is a stable continental plate (see "Eggshell Earth") but regional stresses and geological structures due cause occasional earthquakes away from plate margins. At both global and local scales, the pattern of distribution is many small magnitude earthquakes and fewer large magnitude earthquakes.

Preparation

This activity complements "Eggshell Earth" which looks at the global distribution of earthquakes including Canada.

There is a great deal of earthquake information available online and sorting through it can be overwhelming. When looking at different sources note that some data sets will include everything a seismic station recorded, including mine blasts that are not relevant here. Others will filter data and only include certain magnitudes or locations. Western and eastern Canada have their own seismic networks and websites for earthquake information, although they are both operated by Natural Resources Canada (NRCan) and there are many links between the two sites. There is a difference between where an earthquake occurs and where it is felt. Some websites report both or either sets of information. More technical sites report the different types of earthquake magnitude. For this activity, it is acceptable although not scientifically correct to treat them as the same magnitude.

You may prefer to search only for earthquakes in your geographical area. This will mean filtering the data retrieved for location. Students will need to interpret latitude and longitude measurements. Earthquakes do occur in more places across Canada than British Columbia.

The goal is for students to understand the regular occurrence of small earthquakes in Canada, and that occasionally we do have larger events. Feel free to modify the data and search parameters given here, only ensure that this goal is still met.

Activity

Distribute “Shaking Canada Reflections” page and students complete sections 1 and 2: what do they already know about earthquakes in Canada and what questions do they have. They read page 13 of “Dancing Elephants and Floating Continents” that explains the relative damage from earthquakes of different magnitudes.

Provide the student pages and access to the Internet for students to collect data on earthquake frequency and magnitude. They produce two graphs showing the number of earthquakes with each magnitude for the last month, and during the last two years. Discussion of the mathematical symbols used may be required.

Modification: divide the class into two and assign each group one of the graphing tasks. Share the results afterwards.

Close

Students complete sections 3, 4, and 5 of the reflection page: what have they learned, why this information is important, and what questions they still have.

Allow time to respond to students’ questions from section 5; some may be answered quickly and others require further research.

Share the idea that Lithoprobe has been investigating why we have earthquakes in Canada, and finding out more information about how often and how large.

Students’ data may show a lower number of very small earthquakes ($M < 1$). Discussion might be worthwhile as to how we know an earthquake has happened: a seismic station has to record it. Very small earthquakes are easily missed if they do not occur close to a station.

Additional Information Sources

In addition to the NRCan resources used in the activity, there are two definitive sources of global earthquake information for seismologists. Both provide the ability to search the list of earthquakes by location, size, or date, amongst many other features. Some of their pages and references are quite technical, but the information is unbeatable.

NEIC: National Earthquake Information Center of the United States Geological Survey

http://neic.usgs.gov/

IRIS: Incorporated Research Institutions for Seismology (See “Eggshell Earth” for more details about IRIS)

http://www.iris.edu/

Sample Student Responses

M = reported earthquake magnitude. Sample data:

Earthquakes in Canada *January 2004*

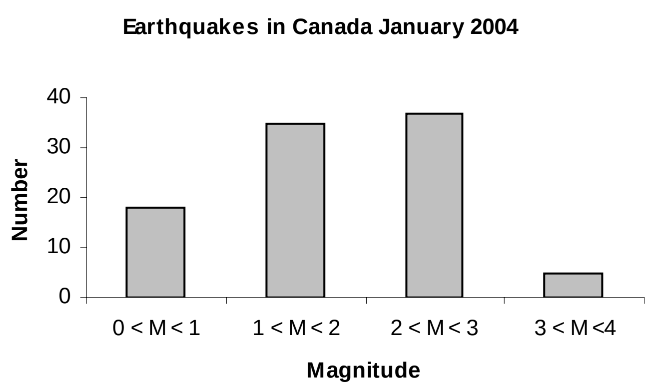
0 < M < 1	1 < M < 2	2 < M < 3	3 < M <4
18	*35*	*37*	*5*

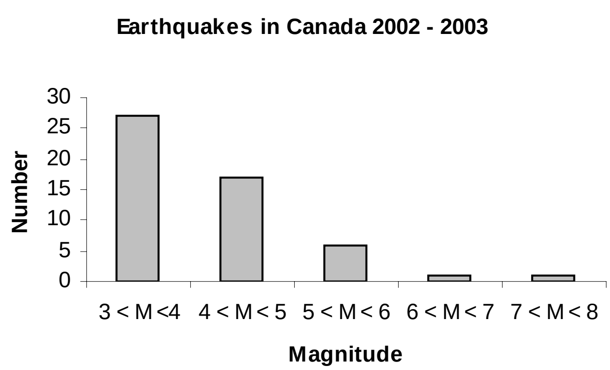
Significant (M > 3) Earthquakes in Canada *during 2002 and 2003*

3 < M < 4	4 < M < 5	5 < M < 6	6 < M < 7	7 < M < 8
27	*17*	*6*	*1*	*1*

Create two bar charts showing the how many earthquakes of each magnitude (size) have occurred in Canada during the last month, and during the last 2 years. On the horizontal axis, show the magnitude of the earthquakes, and on the vertical axis the number of earthquakes.

Using the data above:





Student reflection chart:

Sections 3 and 4: what have they learned and why is this information important will reveal students' interpretation of the data. Earthquakes are not unusual in Canada, but people need to know that most of these earthquakes are small and do not cause damage.

Shaking Canada

What is the risk in Canada from earthquakes?

Materials

Computer with Internet access
Graph paper
"Dancing Elephants and Floating Continents"

Keywords

Magnitude
Earthquake

Book Connections

Pages 12 and 13

Safety When using the Internet, never give out any personal information. Use only the websites listed in the activity.

Instructions

Complete boxes 1 and 2 on the reflections page: what do you already know about earthquakes and what do you wonder?

Read the text box "Rating a Quake" on page 13 of "Dancing Elephants and Floating Continents" which tells you about earthquake magnitude.

Task 1

Use the Internet to access the Pacific Geoscience Centre of Natural Resources Canada (NRCan) website and collect data about all earthquakes in the last month. Use both the "western Canada" and the "eastern Canada" listings found at:

http://www.pgc.nrcan.gc.ca/seismo/recent/50.htm

Record your data on the tally sheet below, where M = earthquake magnitude.

0 < M < 1	1 < M < 2	2 < M < 3	3 < M <4	4 < M < 5	5 < M < 6

Task 2

Collect data about larger magnitude earthquakes in the last 2 years. Use the link for "significant Canadian earthquake reports 1995 to present" on the NRCan website:

http://www.seismo.nrcan.gc.ca/eqinfo/index_e.php

Record your data on the tally sheet below

3 < M <4	4 < M < 5	5 < M < 6	6 < M < 7	7 < M < 8

Analysis

Create two bar charts showing how many earthquakes of each magnitude (size) have occurred in Canada during the last month, and during the last 2 years. On the horizontal axis, show the magnitude of the earthquakes, and on the vertical axis the number of earthquakes.

Complete boxes 3, 4, and 5 on your reflection page.

Shaking Canada Reflections

1 What do you know already about earthquakes in Canada?

2 What do you wonder about earthquakes in Canada?

3 What have you learned from looking at the earthquake information?

4 Why is this information important to people in Canada?

5 What questions do you still have about earthquakes in Canada?

Time	Grouping	Keywords	Book Connections	Activity
	Groups of 6	Reflection Seismic Dancing Elephants Wave Crust Speed Average	Pages 6 and 7	

Dancing on the World

Main Theme

Lithoprobe’s seismic exploration technique discovers layers in the Earth’s crust by bouncing waves down from the surface. The time it takes for the wave to come back up tells them the depth to features deep in the Earth.

Students’ Tasks

Simulate a seismic wave travelling from the surface to a rock layer in the Earth, being reflected back up, and recorded at the surface. First they measure average velocity of a “wave,” then they calculate the distance to each layer using this average velocity.

Materials

Stopwatches (1 per group)
100 m tape
4 markers e.g. buckets, pylons, boxes
Copies of rock cards and student task cards
Sidewalk chalk
“Dancing Elephants and Floating Continents”
Recording sheet for class average (see reproducible)
(Chart paper)
(Overhead projector)

Health and Safety

Carry out this activity in a safe area, away from traffic. Wear clothing suitable for the weather, with sun protection if necessary. Students are to walk, not run. This is not a race. Assign any student with health concerns who does not normally participate in physical education as a timer or recorder.

Lesson Outline

Background The simulation follows the steps used in seismic reflection surveying. First the time for a wave to travel a known distance is measured. From this, the average speed is calculated. Then the time for the wave to travel an unknown distance is measured. The unknown distance is calculated using the time taken and average speed of the wave.

Preparation Before the lesson, make copies of the student task cards, each group of 6 a different colour. For example, a group of 24 students would need:

Group 1 Red	Group 2 Blue	Group 3 Green	Group 4 Yellow
Truck	Truck	Truck	Truck
Computer	Computer	Computer	Computer
Wave 1	Wave 1	Wave 1	Wave 1
Wave 2	Wave 2	Wave 2	Wave 2
Wave 3	Wave 3	Wave 3	Wave 3
Wave 4	Wave 4	Wave 4	Wave 4

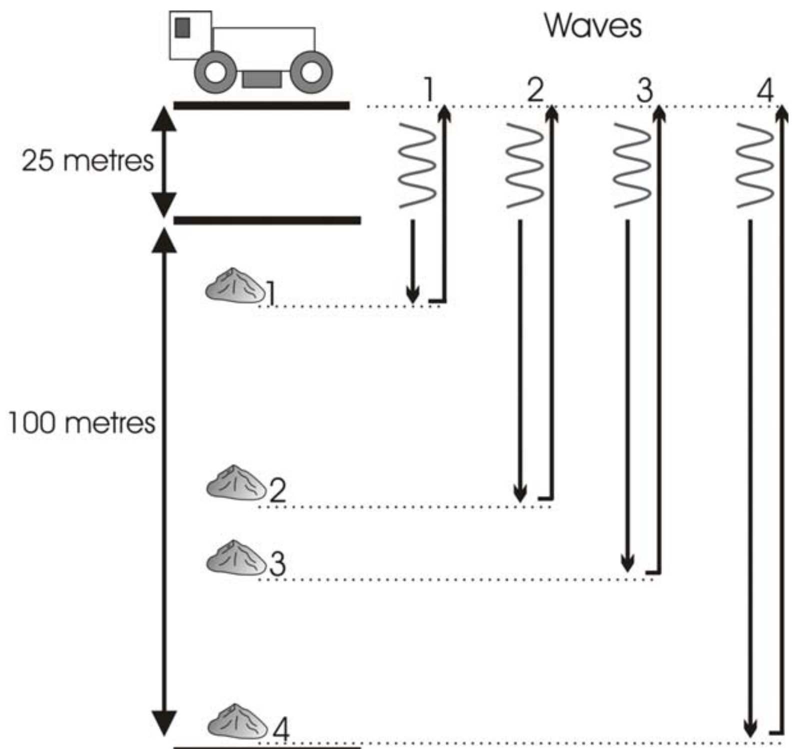
Make 4 copies of the rock cards for the markers. Clearly number each card 1, 2, 3, and 4.

Using the chalk, mark out a start line, a parallel line at 25 metres from the start, and a third parallel line at approximately 100 m from the start. Each line needs to be long enough for the class to stand along it.

Randomly place the 4 markers at any point along the 100 m distance and fix the rock cards to them. To add an “exploration” flavour, don’t put the rock cards in sequential number order. The aim is to discover which is the closest rock from the time for the wave to reach it.

A comfortable, natural speed of walking for many people is 6 km per hour, or 100 metres in 1 minute. The distances have been chosen based on this speed to give suitable times for students to measure.

See the illustration below for the layout of the activity, and how each wave will travel in Part 2.



Activity

Pose the question to students: How do earth scientists find out what’s beneath our feet? Allow students to freely speculate and offer solutions, without correction.

Read aloud page 6 of “Dancing Elephants and Floating Continents” that introduces the Dancing Elephants and seismic reflection surveying, up to the beginning sentence on page 7 “ …computers turn the sounds into a picture.”

Explain that Dancing Elephants are too large to bring to the classroom, and instead the whole class will become part of the science to show how it works.

Part 1:

Distribute the student pages. Students calculate the average walking speed for the class. Working in pairs, students time each other walking between the two lines 25 metres apart. Prompt students to try to walk at the same speed throughout both parts of the activity. It’s not a race and they will get better results by keeping their speed constant.

Using the reproducible Recording Sheet for Class Average provided, collect the results from everyone in the class. Calculate the average time to walk 50 m for each person (add the three times and divide by three) and then calculate the class average walking speed over this distance.

The chart could be copied onto a large piece of paper and prominently displayed to help collect data from the whole group and demonstrate how the average is calculated.

Part 2:

Students simulate a seismic reflection exploration survey. Distribute student task cards to each group. Students take on the roles presented on the cards: the vibroseis truck (the "Dancing Elephant"), the travelling sound waves, and the recording computer. Within their group, students record the time for each "Wave" to travel to a corresponding rock marker and return to the start. They then use the average speed of each "Wave" (student) measured in part 1 to calculate the distance to each rock marker.

Modification: the whole class could be signalled to start simultaneously by a single strike of a bell, a starter's pistol, two pieces of wood slapped together, or a large object dropped on the ground. The latter would be a more authentic replication of the Dancing Elephant seismic method, which uses an impact to create the sound waves.

Repeat the activity if time is available, redistributing cards to switch roles.

The trick to this simulation is when the time is changed into distance. It is assumed that the Waves travel at the average speed calculated in Part 1. If the time for the Wave to travel an unknown distance is measured, the distance can be calculated from the relationship that

speed = distance / time

Rearranging this equation

distance = speed x time

Allow time for students to complete the analysis questions on the student page.

Close

Discuss the analysis questions.

Display the reproducible "Schematic of Lithoprobe's exploration technique." The image is modified from page 7 of "Dancing Elephants and Floating Continents" and the text boxes are extracted from page 6. Read through them in number order to explain the seismic reflection technique.

Explain how the activity that students have completed is a direct analogy to how seismic reflection surveying methods operate, where depths to features in the crust are not measured directly, but inferred from the travel time of reflected seismic waves. Scientists find out the average speed of waves in different rocks and so can calculate distance from the measured time and known speed. Students could be prompted to consider the limitations of this method: notably the necessity and challenge of knowing the speed of seismic waves in different parts of the Earth's crust in order to assign absolute depths to features revealed by seismic surveys.

Students complete the sequencing activity to answer the opening question: How do earth scientists find out what's beneath our feet?

Sample Student Responses

1. In Part 1, why did each student have to walk the 50 metres three times?

   It is impossible to walk at exactly the same speed all the time. By taking 3 different measurements and calculating the average time, it better represents a fair number for the speed to use in Part 2.

2. In Part 2 you found out how far the rock markers were from the start line. Are these distances exact measurements or estimates? *Estimate.*

   Explain why. *The waves did not arrive at the same time in each trial. An average speed is used to convert time to distance.*

3. In your own words, explain the steps used to find out the distance to the markers.

   Measure the time to travel a known distance.
   Calculate the average speed.
   Measure the time to travel an unknown distance.
   Calculate the unknown distance using the time taken and average speed.

How Do Earth Scientists Find Out What's Beneath Our Feet?

Put the steps in the correct sequence for how Lithoprobe's Dancing Elephants discover what's in the Earth's crust beneath us.

Scientists measure the amount of time it takes the waves to arrive back at the surface. 6

Dancing Elephants pound the ground with huge hammers and make it shake. 1

When the waves hit something in the Earth's crust, they bounce back to the surface. 3

Microphone receivers pick up the sound of the waves being reflected back. 4

They find out how far below the Earth's surface the object is using the speed of the wave. 7

A computer turns the sounds into a picture. 5

The hammers that pound the ground create waves that spread out in all directions. 2

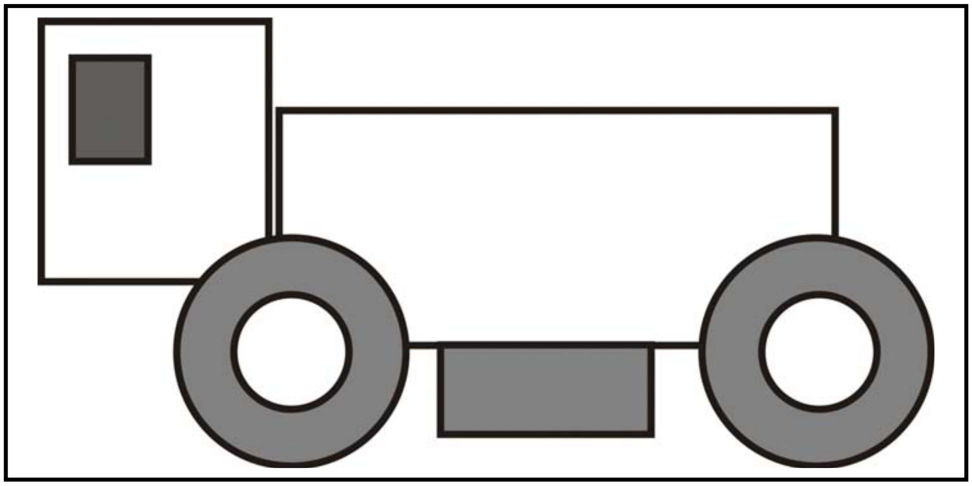
Part 1: Recording Sheet for Class Average

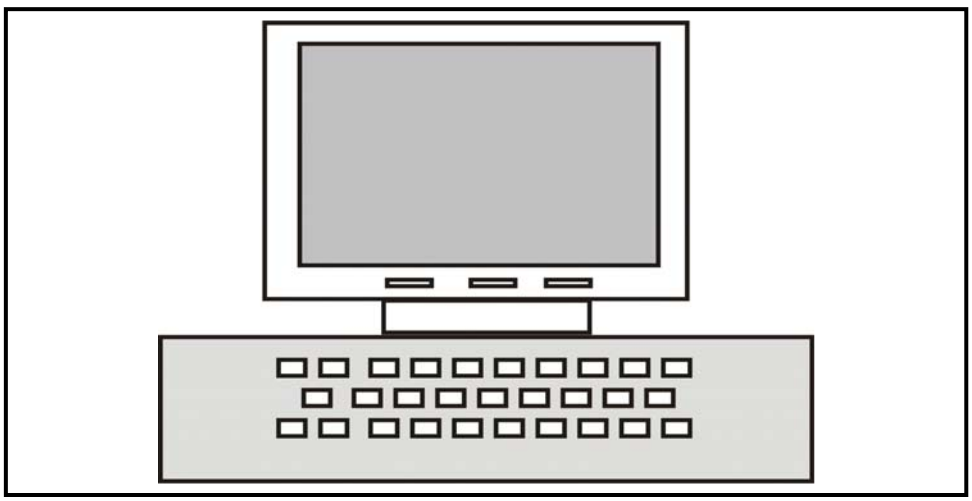
Name	Time to walk 50 m (= 2 x 25 m) (seconds)			Average time to walk 50 m = (T1 + T2 +T3)/3 (seconds)
	T1	T2	T3	

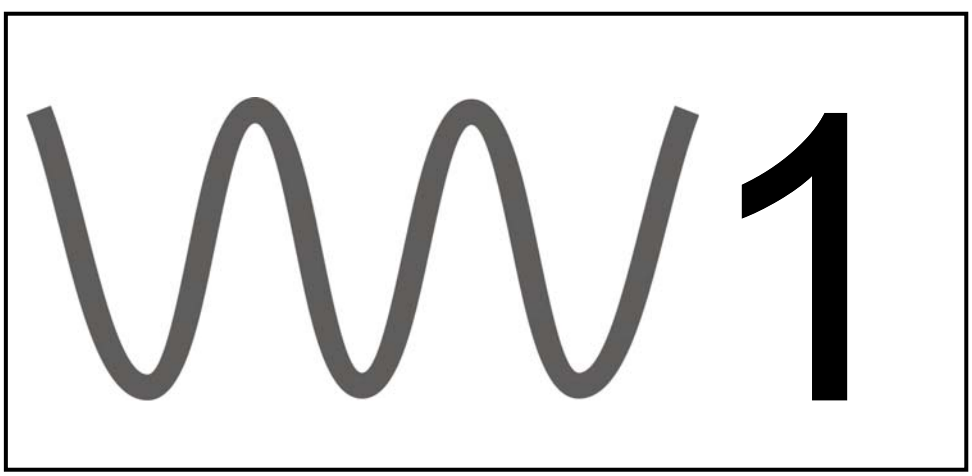
Number of people		Sum of all average times	
		Average time to walk 50 m for class = sum / number of people (seconds)	s
		Average speed of each person in class = 50 / average time (metres per second)	m/s

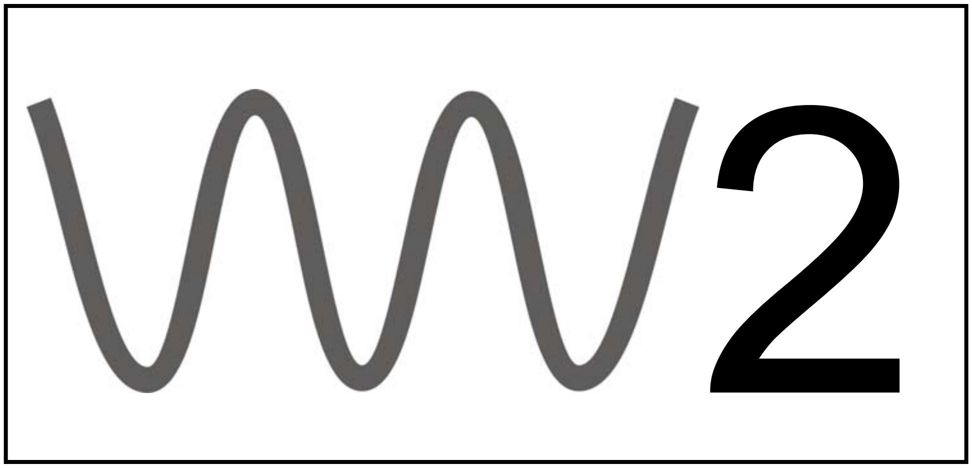
Student Task Cards

Make one set of 6 for each group of students.





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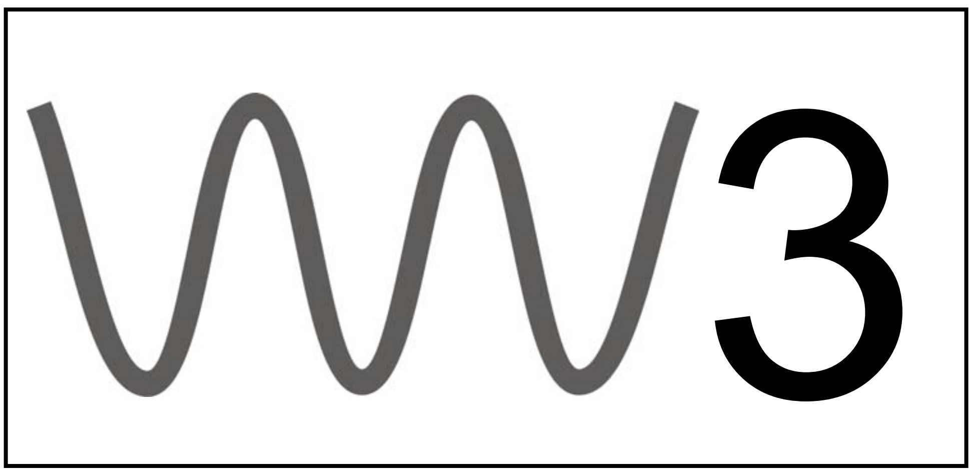
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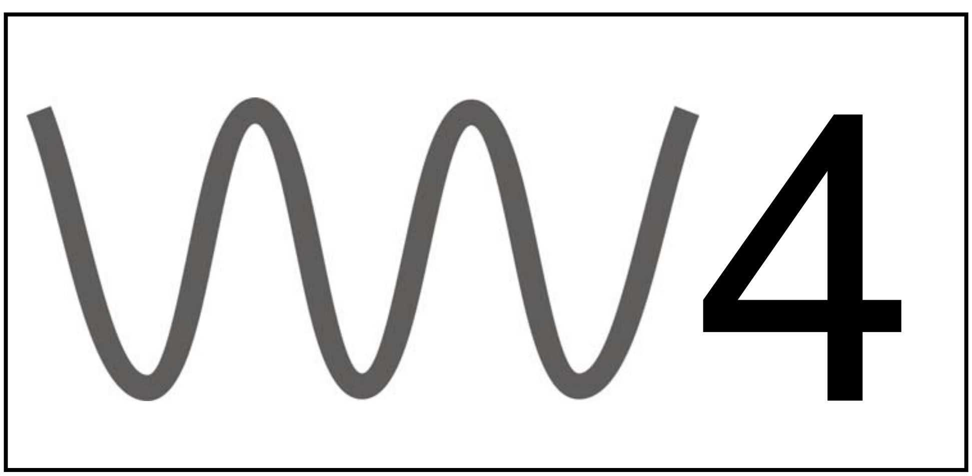
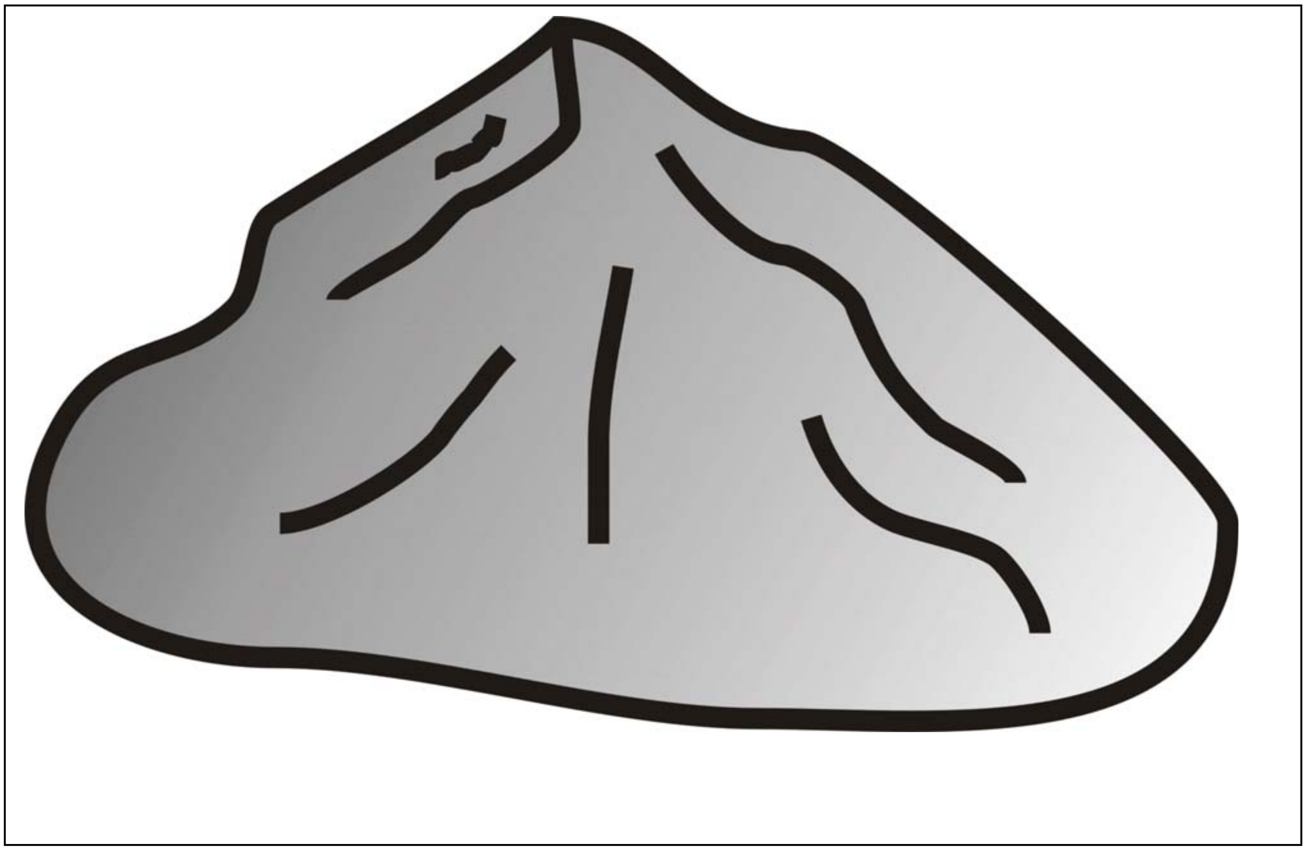

4

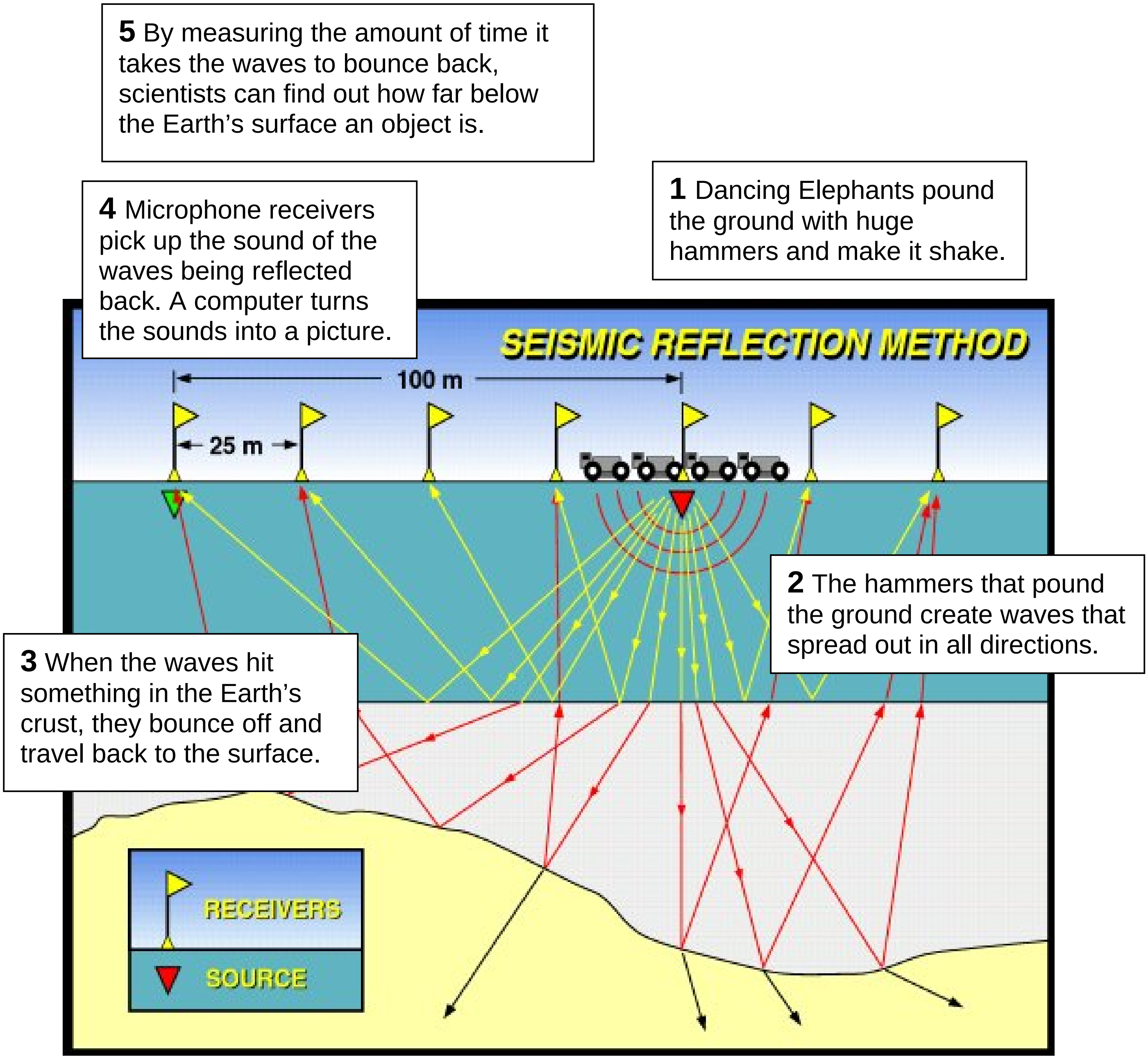
Rock Card

Make 4 copies of the rock marker card and clearly number each 1, 2, 3 and 4.



Schematic of Lithoprobe's Exploration Technique

(Source: Lithoprobe www.lithoprobe.ca)



Dancing on the World

How do earth scientists find out what's beneath our feet?

Materials

Stopwatch
Student task cards
Group of 6 people

Keywords

Reflection
Seismic
Dancing Elephants
Wave
Crust
Speed
Average

Book Connections

Pages 6 and 7

Safety	Carry out this activity in a safe area, away from traffic. Wear clothing suitable for the weather, with sun protection if necessary. Walk only; do not run. This is not a race.

Instructions

Part 1

Work with a partner. Use the stopwatch to time how long it takes for your partner to walk from the start to the line at 25 metres and return. Walk naturally, trying to keep at the same speed.

Switch roles and have your partner time you.

Repeat both measurements 3 times, record each time on the chart below.

Time to walk 2 x 25 m (seconds)	Person 1	Person 2
Time 1	s	s
Time 2	s	s
Time 3	s	s

Add your times to the Recording Sheet for the Class Average. When the whole class has finished, calculate the average walking speed for the class.

Part 2

Join into a group of 6 people. Each person in the group takes a card and stands at the start line.

The Truck tells the 4 Waves to start walking and starts the stopwatch.

The Waves walk straight down along the course towards the rock markers.

When a Wave reaches a rock marker with the same number as their card, they turn around and walk back to the start line. For example, Wave 1 walks to rock 1 and back.

As each Wave arrives back at the start line, the Truck announces the time on the stopwatch, and the Computer records it on the chart below. Do not stop the watch; keep it running to time the other Waves.

Repeat the task and record a second time for each Wave.

	Time 1 (seconds)	Time 2 (seconds)	Average time = (Time 1 + Time 2)/2
Example	*27*	*25*	*27 + 25 = 52* *52 / 2 =* ***26*** *seconds*
Wave 1	s	s	s
Wave 2	s	s	s
Wave 3	s	s	s
Wave 4	s	s	s

You only measured the time for each Wave to reach the rocks, but using the calculated average walking speed from part 1, you can find out the distance that each Wave travelled.

Calculate: Distance = time x average speed

Rock	1	2	3	4
Distance from start	m	m	m	m

Analysis

1. In Part 1, why did each student have to walk the 50 metres three times?

2. In Part 2 you found out how far the rock markers were from the start line. Are these distances exact measurements or estimates? Explain why.

3. In your own words, explain the steps used to find out the distance to the markers.

How Do Earth Scientists Find Out What's Beneath Our Feet?

Number the steps in the correct sequence from 1 to 7 for how Lithoprobe's Dancing Elephants discover what's in the Earth's crust beneath us.

Scientists measure the amount of time it takes the waves to arrive back at the surface.	
Dancing Elephants pound the ground with huge hammers and make it shake.	
When the waves hit something in the Earth's crust, they bounce back to the surface.	
Microphone receivers pick up the sound of the waves being reflected back.	
They find out how far below the Earth's surface an object is using the speed of the wave.	
A computer turns the sounds into a picture	
The hammers that pound the ground create waves that spread out in all directions.	

Time	Grouping	Keywords	Book Connections	Activity
		Crater Ejecta Meteor Meteorite	Pages 38 and 39	

Visitors from Space

Main Theme

Many astronomical objects have impacted Earth's surface, leaving surface features, changes to the geology, and believed to affect the climate, causing mass extinctions.

Students' Tasks

Students will use investigate through experiment the relationship between object size and crater dimensions. They evaluate the effect of meteorite impacts on humans.

Materials

"Dancing Elephants and Floating Continents"
"Request for Scientific Evaluation" letter
"Craters on the Moon" handout
"Meteorite Arrivals" data sheet
"Experiment Design Planning" Sheet
Safety goggles
Assorted materials, suggestions include:

- Sand, slightly damp
- Flour
- Cocoa powder
- Kitty litter tray or large dish pan
- Ruler
- Balls of different size: e.g. ping pong ball, tennis ball, marble, golf ball

Health and Safety

Eye protection is recommended.

The balls must fall under the force of gravity only. Do not throw them or use any type of projecting system, e.g. a catapult.

Some students are sensitive to silica, in which case substitute dust free sand, soil, or flour, although flour dust may also be a problem.

Lesson Outline

Background

Meteors are pieces of rock or ice orbiting the Sun that enter the Earth's atmosphere. Those pieces that do not burn up and impact on the Earth's surface are called "meteorites."

With the additional benefit from photographs of Earth taken from space and satellite imaging, about 200 surface features resembling meteorite impact craters have now been identified.

Impact craters have smaller depth/diameter ratio, and lower rims than volcano craters. Impact craters are almost always circular, irrespective of the angle of approach, have particulate ejecta, and sometimes have a central peak, or concentric rims. Volcanic craters are less frequently as symmetrical as impact craters, and have a much wider variety of shapes and profiles.

Preparation

This is a self-directed study investigating and evaluating meteorite impacts.

Create an activity file of the reproducible materials: the “Request for Scientific Evaluation” letter (personalize it for your school), the “Craters on the Moon” image, and the “Meteorite Arrivals Data” sheet. Provide this file to students.

For the experimental design part of the activity, make available in the classroom suitable materials for the investigation. Students can choose from this selection or improvise their own methods. If the sand is slightly damp, it is less likely to spill and craters hold their form better. A thin layer of flour or other contrasting powder on top of the sand makes it easier to see the rim and ejecta spread.

This activity has many possibilities for extensions depending on the local curriculum focus. For example: other variables affecting crater size in the investigation stage, e.g. height of drop, or material on surface; further study of identified impact craters on Earth; impact craters on other planets; literature research of the geological formations caused by impacts; information on the Torino scale which rates the risk factor of near Earth objects; graphing the data in the Earth Impact Database (see below) of crater age and size to look for patterns.

Activity

Students are asked to take on the roles of scientific researchers to report on crater properties and the impact on humans of meteorite strikes.

Students are directed to three sources to complete the report: pages 38 and 39 of “Dancing Elephants and Floating Continents”, an investigation of their own design to answer the question of crater size, and the supplementary information sent with the letter from City Hall (in the activity file).

Before students perform their experiment, evaluate their procedure, with an emphasis on the safety precautions to be followed.

Close

Each group of students shares their results and opinions.

Debate may follow on the difficulties or otherwise of global emergency preparedness, perhaps in the context of the various Hollywood movies dealing with the subject.

Additional Information Sources

Lunar And Planetary Institute of the Universities Space Research Association, USA has an online slide set of terrestrial impact craters, downloadable high-resolution images. http://www.lpi.usra.edu/publications/slidesets/

Earth Impact Database (previously held at NRCan), Planetary and Space Science Centre, University of New Brunswick. Search the crater inventory by location to access aerial photographs and statistics for each identified crater. Many Canadian examples are available. http://www.unb.ca/passc/ImpactDatabase/index.html

Meteorite and Impacts Advisory Committee to the Canadian Space Agency provides information and data in English and French on meteorites, impact structure, fireballs, and a reporting system for sightings. http://miac.uqac.ca/

NASA provides an activity suitable for middle school students interpreting LANDSAT images of craters. Downloadable student worksheets and images, with a teaching plan are available at: http://landsat.gsfc.nasa.gov/education/crater/index.html

Sample Student Responses

This is an individualized investigation that leads to many possible interpretations. The actual evaluation presented in the students' report will largely be opinion, but needs to be based on fact. Those facts will include:

Larger objects produce larger craters: diameter, rim, depth and ejecta spread.

Crater diameter is significantly larger than the object.

Earth and Moon have been subject to similar meteorite collisions during their history. There are fewer visible craters on Earth because the atmosphere burns up many smaller meteors, and geological processes of tectonics and erosion remove surface evidence.

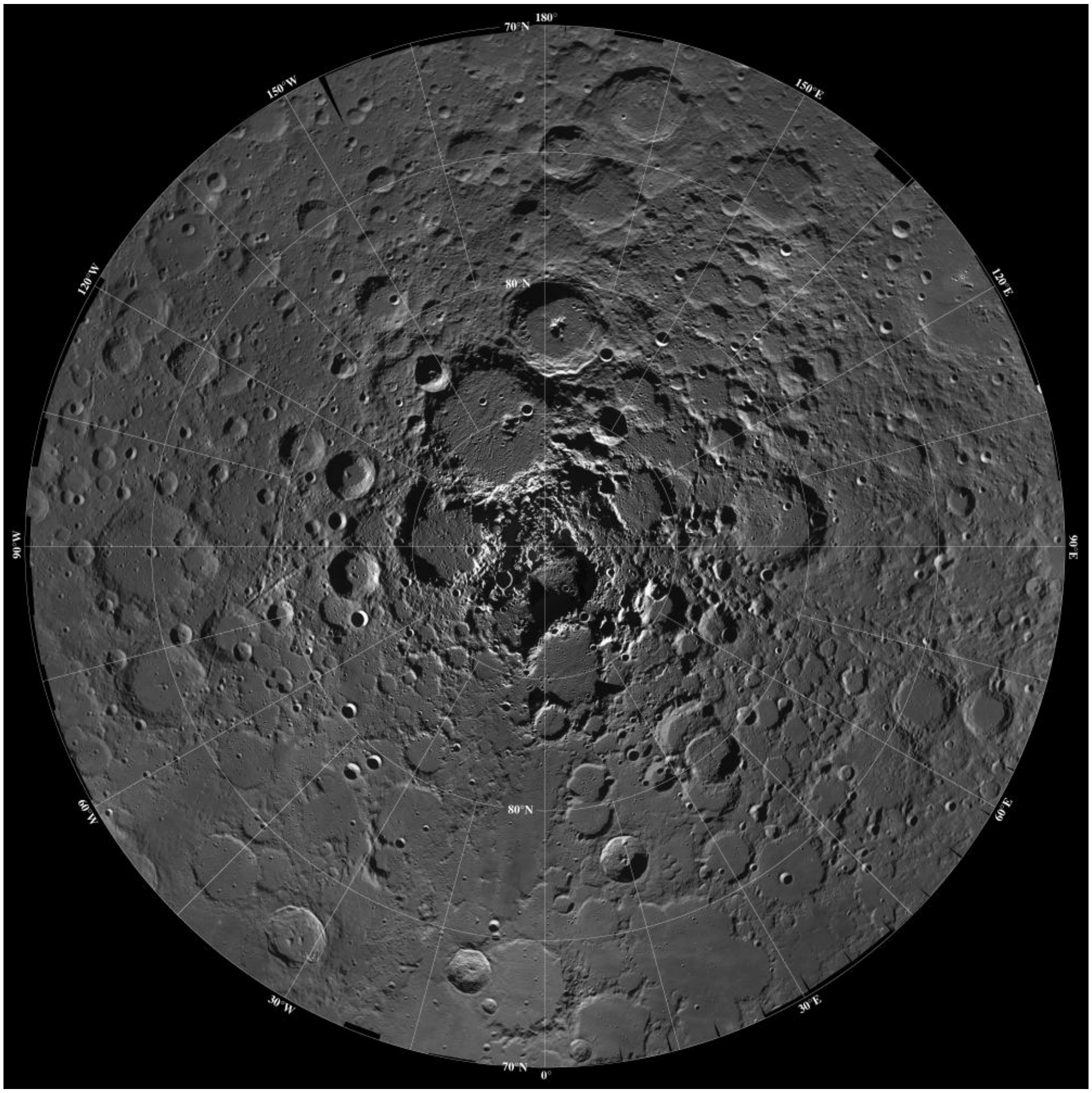
Earth experiences many small meteorites causing little or no damage. Larger damaging events are very rare.

Extremely large meteorite impacts, such as that which caused the Chicxulub crater described on page 38 of "Dancing Elephants and Floating Continents", have been linked to climate change and mass extinctions of life on Earth.

Students' justification as to how a society should prepare for a meteorite strike may cover such topics as economics, the relative time scale of major impacts, the relative scale of human effort or influence versus the global catastrophic effects, the nature of prediction and warning time for a large impact, possible patterns of meteor occurrence over time.

Craters on the Moon

This part of the Moon shown in this picture is about 1000 kilometres wide. The largest crater in the centre is 150 kilometres wide.



Source: http://antwrp.gsfc.nasa.gov/apod/image/9803/lunarnorth_clem_big.jpg

What do you think made these craters on the Moon?

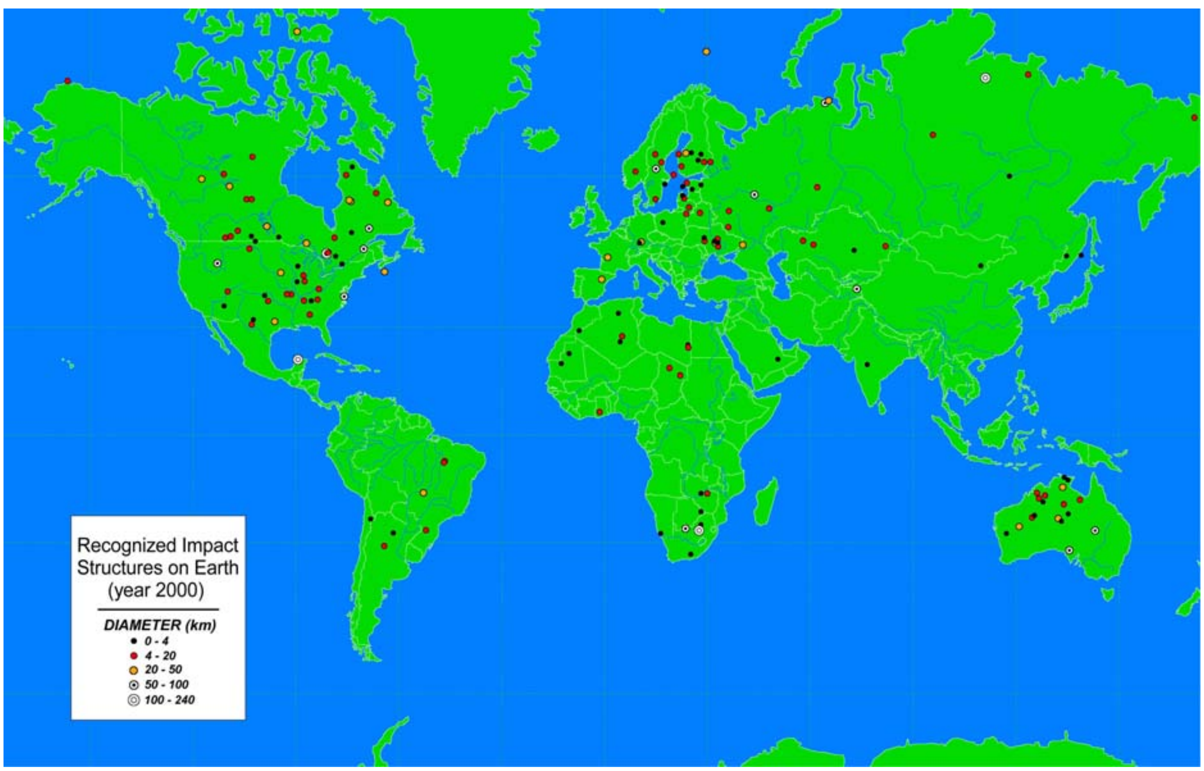
Do you think these craters were all formed at the same time or over a long period?

What do you think was happening to Earth as these craters were being formed on the Moon?

Meteorite Arrivals Data Sheet

Time Period	Size of Meteor	Damage Scale on Earth
Every hour	1 centimetre	None
Monthly	30 centimetres	Like a severe hail storm
Hundreds of years	10 – 100 metres	Regional disaster
Thousands of years	100 metres – 1 kilometre	Greatest known natural hazards
100 million years	10 km	Global catastrophe

Identified Impact Craters on Earth



Request for Scientific Evaluation

Department of Emergency Preparedness

City Hall

Your town

Your Province or Territory

Canada

Today's date, 2004

Dear Earth Science Researchers,

The emergency preparedness team at City Hall has received information from a lobby group concerning meteorite impacts. Copies of this information have been enclosed: an image of the surface of the Moon, data predicting the frequency and size of meteorites arriving on Earth, and a map showing the impact craters identified on Earth. We are looking for expert advice from your earth science team as to how we should respond to this information in an emergency plan for our community.

Please send us a report that includes the following information:

- *Data showing how impact crater size is related to the meteorite size*
- *Your opinion about the risk to Earth from meteorite impacts*
- *Explanation of why we can see more craters on the Moon than the Earth*
- *Your recommendations about how we should plan for these impacts, with reasons for your suggestions.*

Yours sincerely,

Director of Emergency Preparedness

Visitors from Space

What happens if a meteor collides with Earth?

Materials

"Dancing Elephants and Floating Continents"

"Request for Scientific Evaluation" letter

"Craters on the Moon" image

"Meteorite Arrivals Data" sheet

"Experiment Design" sheet
Investigation materials

Safety goggles

Keywords

Crater
Ejecta
Meteor
Meteorite

Book Connections

Pages 38 and 39

Safety Wear safety goggles during your investigation. Only drop the balls, do not throw them.

Instructions

Your team has received a request from City Hall to help with an earth science issue. Review the letter and information in the activity file.

Your group will produce a report for City Hall to answer their questions about the effects of meteorite impacts on Earth and how should they prepare for them.

To produce your report, you will do three things:

1 Design and carry out an investigation to find out how the crater size is dependent on meteorite size. Use the experiment design sheet to guide you.

2 Read pages 38 and 39 of "Dancing Elephants and Floating Continents"

3 Review the information that was included in the letter from City Hall.

When you produce your report, make sure that you answer all the questions in the letter.

Experiment Design Plannning Sheet

How will you record your results?

What materials will you use?

What is the question to answer?

How will you make sure it is a fair test?

How will you carry out your investigation?

What safety precautions will you follow?

Time	Grouping	Keywords	Book Connections	Activity
Two sessions, at least 2 days apart		Dissolve Ground water Mineral Ore	Pages 40and 41	

Moving Minerals

Main Theme

Many important and valuable mineral resource locations are found at plate boundaries, rift zones, and impact craters. Canada has abundant and economically important natural resources.

Students' Tasks

Carry out an investigation to show how liquids can move and concentrate minerals from one place to another.

Research natural resources for Canada and their local area.

Materials

2 containers, approx 2 cups each
1 cup hot water
2 cups solute (see lesson preparation)
Thick yarn, approx 20 cm (dark colour preferred)
Spoon for stirring
Sheet paper (dark colour preferred)
(1 cup measure)
Scavenger Hunt sheet
Supplementary research materials (see lesson preparation)
"Dancing Elephants and Floating Continents"

Health and Safety

Water spills must be cleaned up immediately. Additional safety precautions may be needed if boiling water or laboratory chemicals are used - see the lesson preparation.

Lesson Outline

Background

Many mineral occurrences of economic importance are related to fluid flow through rocks. Water heated at depths in the Earth dissolves minerals from the surrounding rocks. As the water passes through fissures and weaknesses in the rock layers, temperature and pressure conditions change, and minerals crystallize or precipitate out from the water in new locations. It is possible for minerals to be highly concentrated in these sites, which are often defined by structures within the Earth's crust, such as fault zones, fractures around intrusions, or sedimentary layers. The mineral ore bodies formed this way are found as veins and pipes, and are referred to as hydrothermal deposits. Gold and copper are commonly found as hydrothermal ore deposits. Lithoprobe's work defining and exploring structures in the crust is therefore beneficial in explaining where valuable minerals may occur.

Preparation

This activity is in two separate parts: the crystallization experiment and research on natural resources. They may be completed concurrently or consecutively to effectively use the lesson time available.

The solute used to make the crystals can be a variety of household substances, for example sugar, water softener salt, Epsom salts, or fruit drink crystals. It is not necessary to use laboratory chemicals (e.g. copper sulphate) but if used, it is essential that the Materials Safety Data Sheet for each chemical be obtained, which describes the health and safety precautions that must be followed.

Make the water as hot as safe practice allows. If students are responsible and trained to use heat sources, boiling water allows more solute to be added. Recently boiled water in an insulated jug, or an electric kettle placed in a safe area would be suitable. Direct heat devices such as Bunsen burners are not necessary.

Choose containers that can withstand the temperature of water being used. Deli style tubs will suffice for hot tap water, but if boiling water is being used, heatproof glass will be needed.

Students need to correlate the household materials with their geological equivalents. Label the solute “Minerals in Rock” and label the water “Heated Ground Water” to enhance student interpretation in the activity.

Materials may either be pre-measured or students will require a measuring cup and be instructed in its use.

The aspect being modelled is that water will propagate along the yarn, carrying the dissolved minerals, which then crystallize in another place. This flow will be encouraged if the yarn is first soaked in the mineral-water mix. However, pre-soaking may inhibit students’ interpretation of hydrothermal processes in the crust, where fluid flow is the important issue. Set up the available equipment prior to the student activity and establish if pre-soaking is necessary to see results in the desired time frame.

For the research task, extensive information of the Canadian mining industry, facts and figures can be found online from NRCan at

http://www.nrcan-rncan.gc.ca/mms/scho-ecol/main_e.htm

NRCan also lists provincial sources of information; follow the “Cool Links” icon.

Local information may be obtained from newspapers, phone books, maps, etc.

Activity

Day 1: Provide students with the labelled materials and student page. Students set up the experiment.

From pages 40 and 41 in "Dancing Elephants and Floating Continents" they find information about natural resources in Canada. Using supplementary materials, they research details of natural resources in their local area. Depending on location, this may be at a municipal or provincial scale. Evaluation is made as to why these resources are important.

Day 2: Students observe results of their experiment.

Close

Their observations are applied to a simple geological structure. The sketch may need additional clarification if students are not experienced in seeing cross-section views.

Sample Student Responses

Moving Minerals

Sketch and describe what you see: *Crystals form along the yarn; there may be a column of crystals concentrated where the yarn loops down between the containers.*

What do you think has happened: *The minerals were dissolved in the ground water. The water has soaked/flowed/travelled along the yarn. As the water dries out, the minerals get left behind/crystallize.*

What would happen if it were gold dissolved in the water: *We would get deposits of gold along the yarn.*

Colour on the sketch where you might find deposits of gold: *Gold might concentrate in the cracks to the left of the igneous rock, and in the fault that touches the igneous rock. The second fault is less likely to channel ore deposits since there is no direct path for the ground water. If students indicate gold will be found there, they must be able to justify the route of ground water flow. (The relative permeability of the various rock layers may allow for this, but this concept is not being considered here.)*

Scavenger Hunt

Examples of Canada's natural resources: *"Dancing Elephants and Floating Continents" names nickel, copper, diamonds, gold, platinum, oil, gas. This is only a short example of the extensive variety of resources exploited in Canada.*

Natural resources in your local area: *Consider metals and non-metals, materials either extracted or processed locally.*

Why are these resources important: *Answers depend on local resources. Consider the actual use of the extracted resources, direct and indirect, e.g. manufactured components, also the economic and social benefit to the area and globally.*

What problems may be associated with using these resources: *Answers depend on local resources. Consider environmental issues of extraction methods, habitat loss, noise, traffic congestion, health of workers, depleting non-renewable resources.*

Moving Minerals

Where do we find Earth’s valuable resources?

Materials

2 containers

1 cup “Heated Ground Water”

2 cups “Minerals in Rock”

Thick yarn, approximately 20 cm

Spoon for stirring

Sheet paper

"Dancing Elephants and Floating Continents"

Keywords

Dissolve
Ground water
Mineral
Ore

Book Connections

Pages 40 and 41

Safety	Wipe up any water spills immediately. Follow any extra safety instructions given by your teacher.

Instructions

Put 1 cup heated ground water in a container.

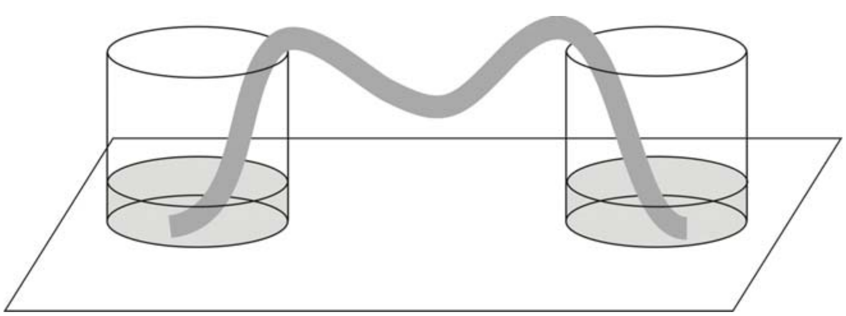
Add one spoon of minerals, and stir until it is dissolved. You should not be able to see any mineral grains in the water.

Keep on adding spoonfuls of minerals, dissolving the minerals each time, until either you run out of minerals or no more minerals will dissolve.

Pour half of the mineral-water mixture into the other container.

Choose a place where the experiment will not be disturbed for 2 days. Stand both containers on a piece of dark paper, with a hands-width between them.

Put one end of the yarn in the mineral-water mixture in one container, and the opposite end in the other container. Let the yarn droop down between the containers, but not touch the paper. Look at the drawing to see the final arrangement. Leave the experiment undisturbed for at least 2 days.

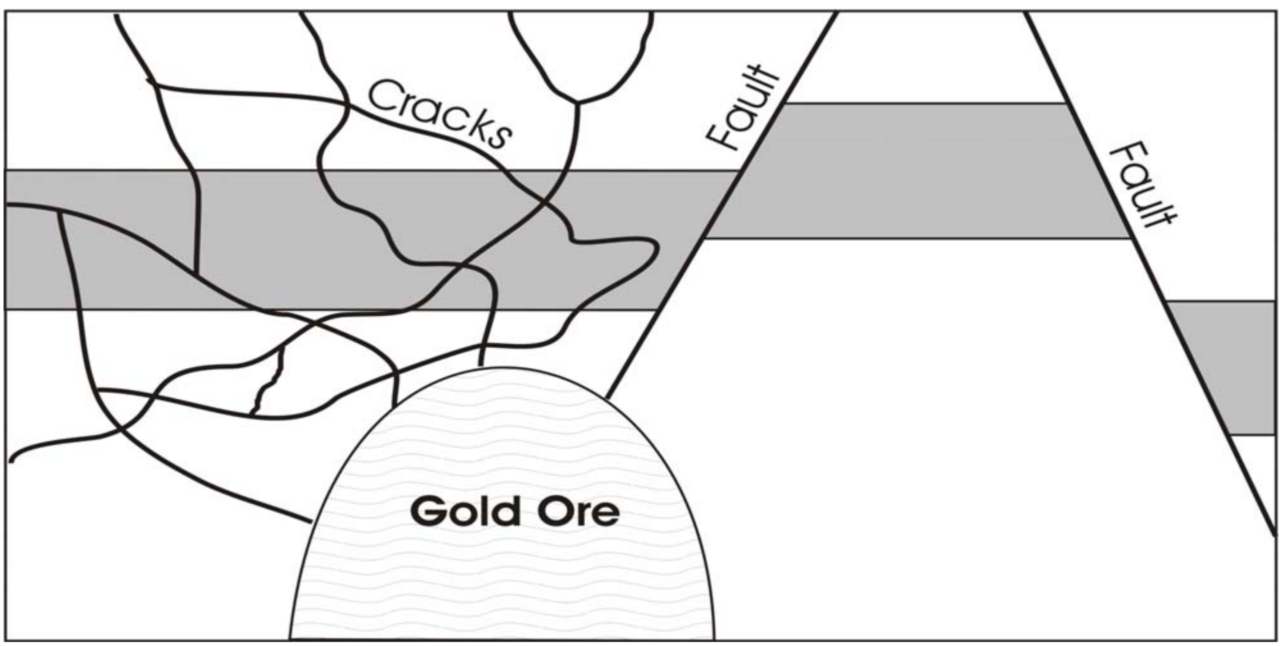


After 2 days, make careful observations of the mineral-water mixture, the yarn and the piece of paper.

Describe what you see.	
What do you think has happened to the ground water and the minerals?	
What would happen if it were gold dissolved in the water?	

The sketch below is a cross section of part of the Earth's crust. An igneous rock that contains large amounts of gold has forced its way up into the rock layers. This has caused many small cracks on one side, and there are also two faults in the area.

Colour on the sketch where you might find deposits of gold that have been moved by ground water, like you saw in your experiment.



Scavenger Hunt

Make a list of some examples of Canada’s natural resources. Collect information from pages 40 and 41 of “Dancing Elephants and Floating Continents”

What natural resources are found in your local area?

Look at your local newspapers, phone book, and maps for information.

Why are these resources important?

What problems may be associated with using these resources?

Time	Grouping	Keywords	Book Connections	Activity
		Radioactive	Page 43	

Happy Birthday

Main Theme

Radioactive dating is used to find out the age of rocks in the Earth.

Students' Tasks

Simulate the principle of radioactive decay and demonstrate how to date a rock from its composition.

Materials

100 pennies
100 plain markers
Stopwatch
Container for a shaker
Calculator
Graph paper
"Dancing Elephants and Floating Continents"
(Hand specimen of gneiss)

Health and Safety

There are no safety issues in this activity.

Lesson Outline

Background

When earth scientists look at rocks, they can often deduce from observations which rocks are younger or older. There are many ways to tell the relative ages of rocks, for example, how the layers are arranged on top of each other, evidence of major events like volcanic eruptions, faults and floods, or the types of fossils in each rock.

These observations cannot tell the actual age of the rocks. To get an absolute date for when a rock was formed, earth scientists use radioactive dating.

Many rocks contain atoms of certain elements that are radioactive. These radioactive atoms are unstable, and will change into atoms of different elements that are stable. This process is called radioactive decay. Decay occurs by the atom losing protons neutrons, electrons and/or energy. It is these emitted particles or energy that are called radioactivity as they leave the atom. When a rock is formed, a fixed amount of radioactive atoms are trapped in the rock. As time progresses, each radioactive atom, called the parent, will decay to a stable (non-radioactive) daughter atom. Although the decay of individual atoms is random, when considering a large number (millions) of atoms each radioactive element has a characteristic time during which half of the parent atoms present will decay to their stable daughter atoms. This time is called the half-life of that parent element. Measuring the ratio of the parent to daughter atoms and knowing the half-life of the parent element can determine the age of the rock in which they occur.

Preparation

Materials can be substituted with whatever is available. The principle is to provide two sets of counters: one represents the unstable radioactive parent atoms and must be able to change from one state to another. For example, coins can be heads or tails; playing cards can be face or back; die can roll 1 or 6 (or any designated number), counters can be plain or marked. The other set represents the stable daughter atoms so do not change and are the same on both sides.

The starting number of 100 pennies is arbitrary and can also be adjusted depending on materials and time available, and students' abilities. The proportion of pennies that decays in each throw is not dependent on how many pennies there are.

Some versions of this activity available elsewhere simply remove counters when they decay. Here they are replaced with plain markers to emphasize that when radioactive atoms decay in rocks, they don't disappear but change into something else.

To increase the realism of this simulation, it is worth the effort to produce a set of 100 cards labelled on one side "uranium" and the other "lead." Used in place of the pennies, cards showing "lead" are removed and replaced with plain markers, symbolizing that the radioactive uranium has decayed to its stable daughter product, lead.

In real laboratory analysis, the data plotted is the ratio of parent to daughter atoms, but this becomes very small and really needs a logarithmic plot. Here students plot the ratio of daughter to parent, which makes it more suitable for middle school students. Using calculators is recommended, with guidance as to best use of decimal places and how to plot a graph using decimal numbers.

Activity

Show the illustration on page 43 of a slab of Acasta Gneiss. (If possible, have a hand specimen of similar gneiss for students to take a closer look.) Prompt students:

"Scientists claim that this rock is the oldest rock in the world, and it was found in Canada. But how do they know?

"Dancing Elephants and Floating Continents" shows that Lithoprobe scientists are telling the story of how the Canada beneath our feet grew and changed. To describe its history, they need to be able to tell how old the rocks are that they are looking at. Again, how do they know?

One of the best ways is to measure tiny amounts of radioactivity in the rocks. We can't use real radioactive material in the classroom, but we can do an activity to show how radioactive dating works."

Students work alone or in pairs following the student handout simulating a radioactive decay process.

This activity could be extended to use class averages to plot the decay graphs, which simulates the laboratory process in both dating and establishing half-lives for isotopes where many repeated measurements are averaged.

Extend and supplement the activity by setting up boxes containing different ratios of pennies and markers. Students use their experiment results to decide how many half-lives had passed for each box. Initially, use the same total numbers as in the experiment (100) and move onto different total numbers so that the ratio of daughter (decayed) to parent (original) has to be used.

Close

Question 6 prompts students to make the connection that each "throw" represents a fixed time period, the radioactive half-life of the parent chemical. Review this question with students, and reveal the accepted age for the Acasta Gneiss is 4 billion years. If the timeline activity "Millions of Years" has been completed, add this entry to the history of the Earth.

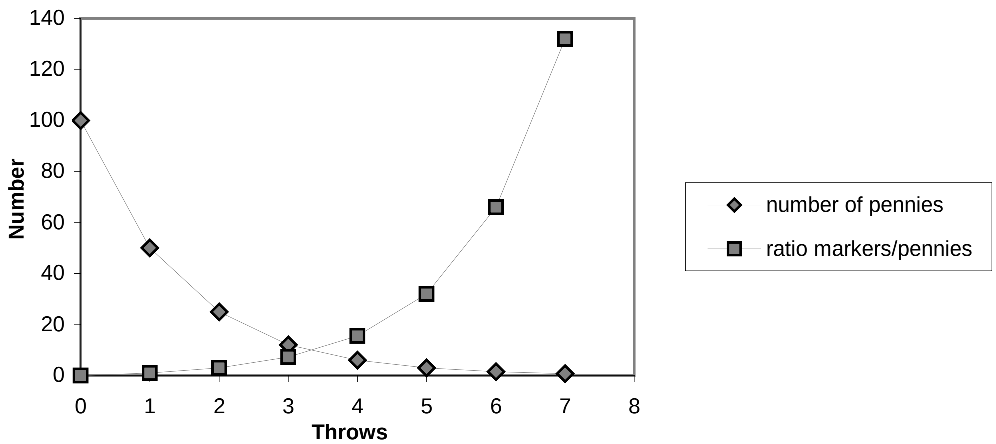
Sample Student Responses

1. Plot a graph of the number of pennies left against number of throws.

2. From your graph, after how many throws were ½ of the original pennies remaining?

Statistically, the chance of any penny decaying into a head is 50:50. So it is reasonable to expect to remove ½ of the pennies on the first throw. This is only a probability, and students must answer from their graph.

3. In the third column of your recording chart, calculate the number of “heads” removed divided by the number of pennies remaining. Plot a graph of this ratio against number of throws.
As per students’ results, it should be a graph of increasing slope.
The two plots on the sample graph below have been created with synthetic data.



4. How do you think your graph in question 3 would look if you had started with 500 pennies?

This is the key to isotopic dating and a difficult concept: the graph should be the same since it shows the ratio of pennies in their original and decayed state. This ratio is not dependent on initial total number, and by measuring the ratio in a rock, we can tell how long ago the rock was formed.

5. In an experiment following the same rules but with a larger number of pennies, groups of students were stopped after different number of throws. How many throws had they made if they had:

a) 200 “heads” removed and 200 pennies left? *1 throw*

b) 500 “heads” removed and 5 pennies left? *8 throw*

c) a ratio of 15 for heads removed / pennies left? *5 throw*

On the principles discussed in question 1, suitable answers are given here, but must be answered from the students’ graphs.

6. Each throw represents one radioactive half-life of chemicals in a rock. The half-life of Uranium is 700 million years. When scientists apply this dating method to the Acasta Gneiss, they find out that the ratio of stable daughter chemical to the parent Uranium is 132. Reading from your graph and using the data given in this question, what would your estimate be for the age of the Acasta Gneiss?

Answers depend on students’ graphs. Age given in “Dancing Elephants and Floating Continents” is 3.96 billion years.

Happy Birthday

How do earth scientists tell how old rocks are?

Materials

100 pennies
100 plain markers
Stopwatch
Container for a shaker
Calculator
Graph paper

Keywords

Radioactive

Book Connections

Page 43

Safety There are no safety issues in this activity.

Instructions

In this experiment, pennies represent radioactive “parent” chemicals. If a penny turns up heads, it has decayed into its safe “daughter” chemical, and plain markers that cannot change any more replace the penny.

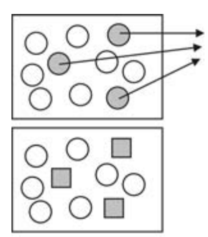
1. Record the total number of pennies and put them in the shaker pot. Shake gently.
2. Tip all the pennies out onto the table.
3. Remove any that show “heads” and replace with plain markers. Record the number of markers on your chart.
4. Shake gently again. Tip out onto the table and again replace all that show “heads” with plain markers.
5. Repeat shaking and removing for 10 throws or until you run out of pennies.

Example:

First throw: Remove all pennies that show heads.

Replace those removed with plain markers

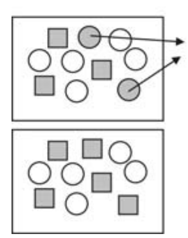
Record 3 markers, 7 pennies



Second throw: Remove all pennies that show heads.

Replace those removed with plain markers,

Record 5 markers, 5 pennies.



Recording Chart

Start number of pennies =

Time	Number of markers	Number of pennies	Markers / Pennies
Example: 1^{st} throw	*3*	*7*	*3/7 = 0.4*
2^{nd} throw	*5*	*5*	*5/5 = 1.0*
1 throw			
2 throws			
3 throws			
4 throws			
5 throws			
6 throws			
7 throws			
8 throws			
9 throws			
10 throws			

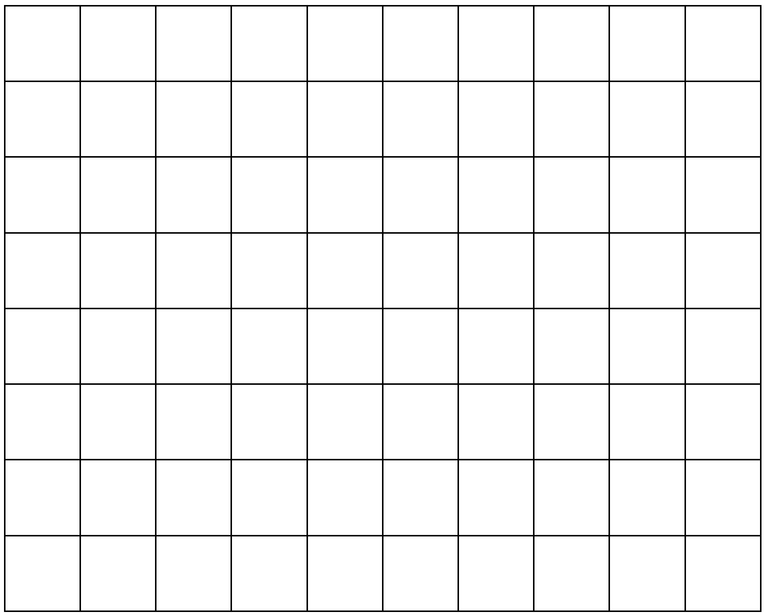
Hint: the number of markers and number of pennies after each throw must always add up to the start number of pennies.

Analysis

1. Plot a graph with the number of throws on the horizontal axis against the number of pennies left on the vertical axis.

2. From your graph, after how many throws were ½ of the original pennies remaining?

3. In the third column of your recording chart, calculate the number of “heads” removed divided by the number of pennies remaining. Plot a graph of this ratio against number of throws.



4. How do you think your graph in question 3 would look if you had started with 500 pennies?

5. In an experiment following the same rules but with a larger number of pennies, groups of students were stopped after different number of throws. How many throws had they made if they had:

   a) 200 “heads” removed and 200 pennies left?

   b) 500 “heads” removed and 5 pennies left?

   c) a ratio of 15 for heads removed / pennies left?

6. Each throw represents one radioactive half-life of chemicals in a rock. The half-life of Uranium is 700 million years. When scientists apply this dating method to the Acasta Gneiss, they find out that the ratio of stable daughter chemical to the parent Uranium is 132. Reading from your graph and using the data given in this question, what would your estimate be for the age of the Acasta Gneiss?

Time	Grouping	Keywords	Book Connections	Activity
		Geologic time	Pages 10 and 11	

Millions of Years (1)

Main Theme

Earth's history is immense, especially when considered in the context of human history. Our recognizable Earth is very young, and the planet has gone through many major changes during geological history.

Students' Tasks

Sequence major events in Earth's history from their prior knowledge and predictions.

Materials

Earth event cards (see reproducible)

Health and Safety

There are no safety issues in this activity.

Lesson Outline

Background The concept of "deep time" such as the immense timescale of the Earth's geological history can be challenging for students to appreciate. Analogies and visual representations aid in building comprehension of deep time. The key is not to remember numbers and dates, but to recognize the sequence and relative ages of major events in Earth's history.

Preparation Reproduce the "Earth Events" cards and cut out. Using card stock and lamination allows the cards to be used for reinforcement, revision, or classroom games.

"Millions of Years (1)" can be used as a stand-alone activity or combined in the same lesson as "Millions of Years (2)".

Activity Provide students with the "Earth Events" cards and student page. Students sequence the events described on the "Earth Events" cards on the blank timeline. The purpose of this prediction is to allow students to focus on changes that have occurred and deduce probable relative relationships from their existing knowledge.

Alternatively: the "Earth Events" cards can be used in a whole group activity. Give one card to each student and have the group cooperatively sequence themselves oldest to youngest.

Close Lead directly into "Millions of Years (2)."

Sample Student Responses

Individual responses are all acceptable; this task probes students' existing ideas, without correction or assessment.

Earth Events Cards

Reproduce onto card and cut out. Randomize sequence before giving to students.

Agriculture begins	Oldest human fossil	Birds appear	Fish appear
Last Ice Age ends	Formation of Alps & Himalayas	Mammals appear	Oxygen-rich atmosphere forms
Neanderthals appear	Extinction of dinosaurs	Dinosaurs appear	Oldest fossil (algae)
Modern humans appear	Formation of Rocky Mountains	Reptiles appear	Oldest Rock
Last Ice Age begins	Flowering plants appear	Land plants appear	The Earth forms

Millions of Years (1)

How old is the Earth?

Materials	Keywords	Book Connections
“Earth Events” cards	Geologic time	Pages 10 and 11

Safety There are no safety issues in this activity.

Instructions

The Earth Event Cards describe major events that have occurred in the Earth’s history.

Put the cards into sequence from what you think is the youngest event to the oldest.

On the timeline, write the events in the sequence you have decided.

Earth Events Timeline

Write each Earth Event in the sequence that you think it occurred in the Earth's history. You can put more than one event on a line, or leave lines blank.

Youngest

Oldest

Time	Grouping	Keywords	Book Connections	Activity
		Geologic time Time scale	Pages 10 and 11	

Millions of Years (2)

Main Theme

See “Millions of Years (1)”

Students’ Tasks

Create a time scale of major events in Earth’s history using an analogy meaningful to them.

Materials

Calculators
Rulers
Art materials of students’ choice
(Geological time scale)

Health and Safety

There are no safety issues in this activity.

Lesson Outline

Background

See “Millions of Years (1)”

Preparation

This activity follows on from “Millions of Years (1)” and may be combined into a single lesson.

Activity

Provide students with the instruction page giving dates for the “Earth Events.” Students create a scaled timeline of these events. Students choose a representation to use and calculate where the major events listed will be placed on their timeline. They present their timescale visually.

Sample representations include: the school day (as in "Dancing Elephants and Floating Continents", pages 10 and 11), one year, 12 hours, the students’ own lifetime, a circle (360 degrees), 10 metres. The timeline can be represented linearly, on a clock face, or in other graphical forms.

Consider at least one student product large enough for public display

Supplementary information can be added to the timeline as work on the unit progresses, especially when the activity “Trip of a Lifetime” about the history of Canada is completed.

In addition to the major events, the timelines can be marked with divisions from the geological timescale, provided as a reproducible.

Close Provide students with the “Millions of Years Reflection” sheet. Students complete the questions, which prompt them to reflect on their initial predictions in part 1, and decide on three important results from creating their timeline.

Sample Student Responses

Assume a 10 metre long timeline. Sample measurements for Earth events at this scale have been calculated below. Even at this scale, the modern human history is too small to plot. For the portion representing modern humans to be 1 cm, the complete timeline must be 1.3 kilometres!

Earth Event	Years before present	Size on the model
Modern humans appear	35 000	*0.08 mm*
Neanderthals appear	110 000	*0.2 mm*
Oldest human fossil	4 million	*9 mm*
Formation of Rocky Mountains	80 million	*17 cm*
Dinosaurs appear	220 million	*48 cm*
Land plants appear	390 million	*84*
Fish appear	505 million	*110cm*
Oldest Rock	3960 million	*= Full size/ 4600 million x 3960 million = 8.6 metres*
The Earth forms	4600 million	*Full size = 10 metres*

Compare your predictions in part 1 to the timeline you have made in part 2.

Which Earth Events did you have out of sequence? *Depends on student’s work*

What reasons did you have for placing these events where you did in your predictions? *Depends on students work.*

Write three pieces of information that are important about the Earth’s geologic history: *Suitable answers might consider the shortness of human presence; that only 1/10th of the Earth’s history has had any recognizable animals; the Rocky Mountains have been formed very recently.*

Geologic Time Scale

ma = million years before present

Phanerozoic Eon (544 ma to present)	Cenozoic Era (65 ma to today)	Quaternary (1.8 ma to today)
		Holocene (11,000 years to today)
		Pleistocene (1.8 ma to 11,000 yrs)
		Tertiary (65 to 1.8 ma) Pliocene (5 to 1.8 ma) Miocene (23 to 5 ma) Oligocene (38 to 23 ma Eocene (54 to 38 ma) Paleocene (65 to 54 ma)
	Mesozoic Era (245 to 65 ma)	Cretaceous (146 to 65 ma)
		Jurassic (208 to 146 ma)
		Triassic (245 to 208 ma)
	Paleozoic Era (544 to 245 ma)	Permian (286 to 245 ma) Carboniferous (360 to 286 ma) Pennsylvanian (325 to 286 ma) Mississippian (360 to 325 ma)
		Devonian (410 to 360 ma)
		Silurian (440 to 410 ma)
		Ordovician (505 to 440 ma)
		Cambrian (544 to 505 ma)
Precambrian Time (4,500 to 544 ma)	Proterozoic Era (2500 to 544 ma)	Neoproterozoic (900 to 544 ma) Vendian (650 to 544 ma)
		Mesoproterozoic (1600 to 900 ma)
		Paleoproterozoic (2500 to 1600 ma)
	Archaean(3800 to 2500 ma)	
	Hadean (4500 to 3800 ma)	

Millions of Years (2)

How old is the Earth?

Materials

Calculators
Rulers
Art materials of your choice

Keywords

Geologic time

Book Connections

Pages 10 and 11

Safety There are no safety issues in this activity.

Instructions

Make a scale model showing events in the Earth's geologic history. Choose a scale and make calculations to find out where to locate the date of each event on your model.

The chart tells you how many years before the present each event occurred and how to calculate the scale.

For example, if your model will be 2 metres long.

The Earth forms at 4600 million years ago

Scale on the model = full size = 2 metres

Oldest rock is 3960 million years ago

Scale on the model = 2 metres/4600 million x 3960 million = 1 metre 72 centimetres

Hints: your scale model does not have to be a straight line; think about clocks or a circle.

Look carefully at he dates: some are millions and some are thousands of years.

Earth Events Dates

Earth Event	Years before present	Size on the model
Agriculture begins	10 000	
Last Ice Age ends	10 000	
Neanderthals appear	110 000	
Modern humans appear	35 000	
Last Ice Age begins	2 million	
Oldest human fossil	4 million	
Formation of Alps & Himalayas	50 million	
Extinction of dinosaurs	65 million	
Formation of Rocky Mountains	80 million	
Flowering plants appear	140 million	
Birds appear	175 million	
Mammals appear	210 million	
Dinosaurs appear	220 million	
Reptiles appear	270 million	
Land plants appear	390 million	
Fish appear	505 million	
Oxygen-rich atmosphere forms	3000 million	
Oldest fossil (algae)	3500 million	
Oldest Rock	3960 million	= Full size/ 4600 million x 3960 million =
The Earth forms	4600 million	Full size =

Millions of Years Reflections

Compare your predictions in part 1 to the timeline you have made in part 2.

Which Earth Events did you have out of sequence?

____

____

What reasons did you have for placing these events where you did in your predictions?

____

____

Write three pieces of information that are important about the Earth's geologic history

1
2
3

Time	Grouping	Keywords	Book Connections	Activity
		Continent Crust Erosion Heat Mantle Ocean basin Rift valley Supercontinent	Pages 28 and 29, 42 and 43	

Supercontinent

Main Theme

The Earth's crust is a patchwork of pieces: old continents, mountain ranges, and closed oceans. Scientists believe a cycle is at work of super continents breaking up and reforming repeatedly over geological time.

Students' Tasks

Cooperative reading to discover the possible stages in the supercontinent cycle. Illustrate the cycle for the rest of the class.

Materials

"Dancing Elephants and Floating Continents"
Group role cards
Supercontinents Break-Up page

Health and Safety

There are no safety issues in this activity.

Lesson Outline

Background The modern continents have at various times in Earth's history been joined together in one huge landmass referred to as a "supercontinent."

In the late 1960's, accomplished and internationally acclaimed Canadian geoscientist J. Tuzo Wilson proposed a theory that supercontinent formation and destruction occurred in repeating cycles, relating to the opening and closing of ocean rifting.

The mechanism of reversal is not well understood: suggestions include separation of crustal materials, onset of subduction, or relative dominance of different mantle convection cells. Each idea itself leads into many more questions.

Preparation Reproduce the Group Role cards onto cardstock.

Activity Students work in groups of 4, each taking a defined role with responsibilities for completing the reading comprehension task. Provide each group with the role cards, the student page, and "Dancing Elephants and Floating Continents".

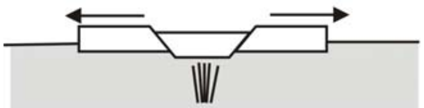
Close Each group devises a demonstration of the supercontinent cycle for the class. Suggestions are a flow chart, cartoon strip, dramatization or speech illustrating the steps in the process. Emphasis at this level is on the stages of the cycle, not the causes.

Complete a concept definition chart for "supercontinent."

Sample Student Responses

Sequence of steps included in the process would be:

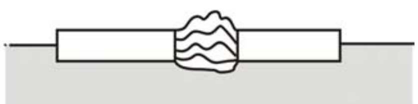
Huge supercontinent
Heat builds up



Rifting
Moving apart

Ocean forming
Separate continents

Motion reverses
Ocean closing



Collision
Mountain forming
Huge supercontinent

Concept Definition for “Supercontinent”:

Definition: *A very large continent, with all the land surface of the world joined together.*

Essential Characteristics: *single continent, large, has occurred in different places on the surface of the Earth, more than one supercontinent has existed in Earth’s geologic history.*

Examples: *Slave (Rodinia, Laurentia, Gondwanaland, Pangea – not in text)*

Not Examples: *Iapetus, Europe, America, Asia, Africa, Australia, Antarctic*

Draw a picture, use it in a sentence, or relate it to something you know: *rift valleys break up supercontinents and mountains form when supercontinents are made.*

Group Role Cards

Coach

Keeps the group on task

Encourages other group members in their roles

Thinker

Finds the keywords

Applies learning strategies to words and ideas not understood

Recorder

Collects ideas from group members'

Writes notes and completes the recording chart

Speaker

Reads aloud instructions and information for the group

Answers questions on behalf of group

Supercontinent

What happened to the Supercontinents?

Materials

“Dancing Elephants and Floating Continents”

Group role cards

Supercontinent Break-up page

Keywords

Continent
Crust
Erosion
Heat
Mantle
Ocean basin
Rift valley
Supercontinent

Book Connections

Pages 28 and 29, 42 and 43

Safety There are no safety issues in this activity.

Instructions

1. Use a cooperative group reading strategy to find out how a supercontinent is formed and destroyed. Each person in your group takes one role from the Group Role Cards: Coach, Thinker, Recorder and Speaker. Use the roles described on your cards, complete the Supercontinent Break-up Page as your group reads pages 28 and 29, and pages 42 and 43.

2. Produce a demonstration of the supercontinent cycle for the class. Your group may choose how to do this. Suggestions are a flowchart, a cartoon strip, a dramatization or a speech.

Supercontinent Break-up

As your group reads pages 28 and 29, and pages 42 and 43, note down the keywords and main ideas, and questions you have or any words you do not understand in the spaces below.

Keywords/Main Ideas

Questions

After reading, first answer any questions.

Strategies that you can use to answer questions include:

Reread the sentence and think what might make sense.

Look for clues in other words, in the same sentence and in sentences before and after.

Break down the word: are there parts that you do recognize?

Use resources to find out what it means: books, dictionary, your teacher.

When all the questions are answered, sort through your notes, and put the important steps in sequence showing the cycle of how a supercontinent is formed and destroyed.

Time	Grouping	Keywords	Book Connections	Activity
		Supercontinent	All	

Trip of a Lifetime

Main Theme

Continents are not fixed; their position and shape have changed over geological time. Canada is made up of many geological parts that represent widely contrasting ancient environments.

Students' Tasks

Visualise ancient environments from descriptions provided. Create a tourist flyer for a supercontinent.

Materials

Trip of a Lifetime destination cards
Art materials

Health and Safety

There are no safety issues in this activity.

Lesson Outline

Background

This activity complements "Supercontinents" in background theory and the timeline activity in "Millions of Years." Precise details of the surface features of these ancient supercontinents are not well defined by rock and fossil evidence, so there is considerable room for imagination and interpretation.

A respected source of maps of how the world has changed through geologic time is the Paleomap Project. View the maps online at http://www.scotese.com/, or educators may purchase materials through the same site.

Preparation

Copy individual destination cards onto cardstock, and distribute one to each student. Students will not know descriptions of the other destinations before the sharing session.

Activity

Provide students with the activity sheet and "Trip of a Lifetime" destination description cards. Prompt students to review the time line in "Millions of Years", or carry out independent research to supplement the basic information on the description cards.

Close

Display and share the students' advertisements. If a display scale timeline was produced in "Millions of Years" place the adverts at the appropriate dates. Discuss together how the information shows the changes that have occurred to Canada through geological time.

Sample Student Responses

Individual student interpretations.

Destination Cards

Trip of a Lifetime
SLAVE

AGE: 2100 MILLION YEARS AGO

CLIMATE: VERY HOT IN THE DAY, FREEZING AT NIGHT

LIFE FORMS: SINGLE CELL ORGANISMS, WITH NO NUCLEUS

CANADA LANDSCAPE:

HUGE OCEAN CONTAINING ODD SHAPED ISLANDS AND VOLCANOES

THIN ATMOSPHERE OF TOXIC GASES

METEORITES MAKING CRATORS

Trip of a Lifetime
RODINIA

AGE: 1100 MILLION YEARS AGO

CLIMATE: LIKE ANTARCTICA TODAY, CONTINENT CENTRED ON THE SOUTH POLE

LIFE FORMS: MICROSCOPIC ALGAE, MULTI CELL ORGANISMS

CANADA LANDSCAPE:

GRENVILLE MOUNTAINS, LARGER THAN THE HIMALAYAS BETWEEN PRESENT DAY MEXICO AND LABRADOR

Trip of a Lifetime
LAURENTIA

AGE: 500 MILLION YEARS AGO

CLIMATE: SIMILAR TO CANADA TODAY

LIFE FORMS: “CAMBRIAN EXPLOSION” OCEANS FULL OF UNUSUAL CREATURES, NOTHING LIKE PRESENT DAY. SOME SIMILAR TO WORMS, JELLYFISH, BEETLES, SEA SLUGS. NO FISH OR LAND PLANTS.

CANADA LANDSCAPE:

IAPETUS OCEAN TO THE SOUTH AND EAST, A SHALLOW SEA TO THE NORTH.

SUBDUCTION AND VOLCANOES OFF PRESENT DAY EAST COAST

Trip of a Lifetime
PANGEA

AGE: 275 MILLION YEARS AGO

CLIMATE: RAINY, EQUATORIAL IN PRESENT DAY NORTHERN CANADA. SOUTHERN CANADA VERY ARID AND MILD TEMPERATURES

LIFE FORMS: LAND PLANTS AND FISH, NO MAMMALS, FLOWERS OR DINOSAURS

CANADA LANDSCAPE:

APPALACHIAN MOUNTAINS ON PRESENT DAY EAST COAST

OCEANS SHRINKING ON WEST, ISLANDS JOINING TO CANADA

Trip of Lifetime

What was it like in Canada millions of years ago?

Materials	Keywords	Book Connections
Destination card	Supercontinent	All
Art materials		

Safety There are no safety issues in this activity.

Instructions

You are the inventor of a time machine and are looking for customers.

Write an advertisement for a “Trip of a Lifetime” eco-adventure to travel back in time to Canada when it was part of one of the supercontinents in the Earth’s geological history.

Your destination is described on the “Trip of a Lifetime” card.

Decide what you will sell to travellers: what will they see? What will be the adventure? Where shall they be visiting? What will they need to bring with them?

Your travel group will follow zero impact tourism rules: take only pictures and leave only footprints. Only what you can carry with you in the time machine will be available from the present day.

Draw up a one-page advert, using pictures and words to attract people to the ancient world.

Display your advert for potential customers to see.

BONUS: Tell your customers where in present day Canada they can see remains of the ancient world they will visit. .

Time	Grouping	Keywords	Book Connections	Activity
		Erosion Sediment Deposition	Pages 32, 33 and 37	13

Vanishing Mountains

Main Theme

Erosion acts to constantly wear away the Earth's surface features. Lithoprobe has shown that mountains bigger than the Himalayas have been eroded beyond recognition during the Earth's history.

Students' Tasks

Students will investigate the process of erosion by water, and its effect upon the landscape.

Materials

Sand
Water
Jug
Stream table (see lesson outline)
Bucket
Piece of old stocking or fine mesh
"Dancing Elephants and Floating Continents"
Recording sheet

Health and Safety

Any water spills must be cleaned up immediately to prevent someone slipping.

Lesson Outline

Background

Erosion refers to the process of wearing away the land, and moving the pieces elsewhere. Weathering is when the surface is broken and changed, but the pieces stay in the same place. Natural agents of erosion are water, ice, wind, organisms, and gravity. This activity looks only at erosion and deposition by flowing water.

How much and what kind of material eroded by water is related to the speed of water flow. Faster water erodes larger grains and greater quantities.

There are many stream and river flow features that may be reproduced by students during their activity. Although not an exhaustive list, this may include ripple marks, diverging and converging channels, meanders, abandoned channels, delta. When water flows around the base of their "mountain" it may cause mass wasting (creep or slumping) as well as the flow features.

The aim of this activity is not to define the physical geography terms, although it can be modified to fulfill that task, but an understanding that the crust can be removed, changed and rebuilt by surface processes.

Preparation

This activity should be carried out before "Mountain Roots".

If you do not have access to a commercial stream table, it is easy to improvise. You need:

a long, smooth waterproof surface, preferably with edges to contain the water.
a way to elevate one end of the surface
a way to collect the water and sand as it flows off the lower end.

Suggestions include a child's slide or a piece of eaves trough. A plastic cafeteria tray, although shorter than preferred, will also work. Use buckets, bowls and jugs to pour and collect the water.

The activity interpretation is enhanced further if sands of different grain sizes are mixed together.

Activity On the stream table, students build a mountain of damp sand. Using water, students investigate the landforms produced by erosion and deposition.

Allow plenty of time for repeated experimentation before students reach conclusions.

Close Question the students: erosion works with sand, but it can't possibly affect giant mountains of rock, can it? Read aloud pages 32 and 33 from "Dancing Elephants and Floating Continents", describing the Grenville Mountains north of Toronto. Show the photographs on both pages: this is what you would see in the Grenvilles.

Conclude with this paragraph, extracted from page 37:

"If you want to climb the Grenville Mountains today, all you need to do is stroll up the gently sloping shore from Georgian Bay. You don't need base camps, special equipment or oxygen tanks. The highest mountains in the world are done –worn down grain of sand by grain of sand into oceans that themselves dried up millions of years before you were born."

(Do not read more of pages 36 or 37, which is looked at further in "Mountain Roots.")

Sample Student Responses

Describe what you observed:

The mountain after water is poured over it: *valleys created, wiggle and curve down the slopes, get wider at the bottom. The mountain is worn away and gets smaller.*

The river down slope: *water goes in wavy lines; sand is spread out along the slope in stripes.*

The mountain after water is poured around it: *the base of the mountain is washed away, the mountainside collapses*

Explain what you think is happening to the mountain, the water and the sand. Try to use the keywords in your answer. *The water is eroding sand from the mountain. The mountain gets smaller. The sediment is transported away by the fast flowing water. As the water slows down on the slope, the sediment (sand) is deposited again.*

Vanishing Mountains

How is our landscape changed by water?

Materials

Sand
Water
Jug
Stream table
Bucket
Piece of old stocking or fine mesh

Keywords

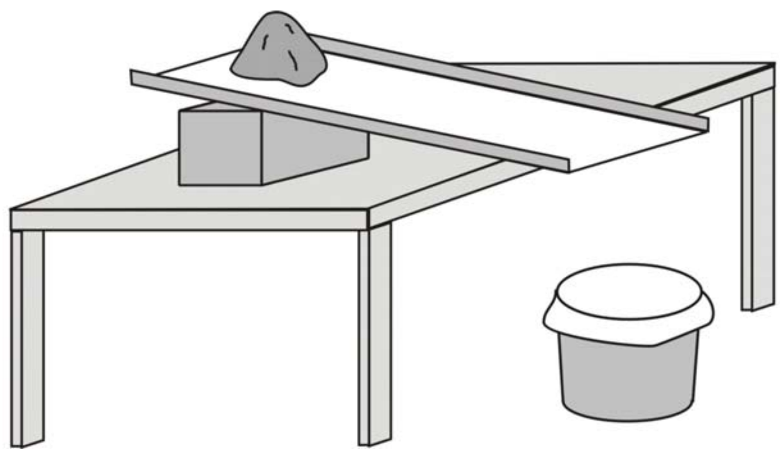
Erosion
Sediment
Deposition

Book Connections

Pages 32, 33 and 37

Safety Any water spills must be cleaned up immediately to prevent someone slipping.

Instructions



Set up the stream table. See the picture for a suitable arrangement.

Put the bucket at the end of the stream table where it will collect water that runs off.

Stretch the mesh over the bucket top to filter the sand out of the run-off water.

Make a mountain from sand at the higher end of the stream table. It may help if the sand is slightly damp.

As you experiment, work slowly and watch carefully. Try things over and over to see if there are any differences. Keep rebuilding the mountain to start again.

Pour water gently on the top of the mountain. What do the valleys look like? The rivers? What happens to the sand?

As the mountain is eroded, what patterns are produced in the sand, both on the mountain and as the river runs down the slope?

How do the patterns change if you pour the water around the base of the mountain?

Are the patterns the same with a steeper mountain or a very gentle hill?

When you have experimented a number of times and have a clear idea of what is happening, sketch and describe your observations on the recording sheet.

Recording Sheet

Sketch and describe what you have seen during your experiment.

	Sketch what you observed	Describe what you observed
The mountain after water is poured over it		
The river down slope		
The mountain after water is poured around it		

Explain what you think is happening to the mountain, the water and the sand. Try to use the keywords in your answer.

Time	Grouping	Keywords	Book Connections	Activity
		Crust Mantle Buoyancy	Pages 34 and 35	

Mountain Roots

Main Theme

Continental crust is less dense than the underlying mantle and effectively floats on the top. To maintain buoyancy, the thicker the crust is, the higher it rises (mountains) and deeper it goes into the Earth (mountain roots).

Students' Tasks

Experiment with floating objects of varying dimensions and investigate the relationship between height and depth relative to the water surface.

Materials

Water
Large tub or sink
Variety of buoyant objects, e.g. cork, wood, Styrofoam, plastic containers
Ruler
Marker pen
Recording chart
Mountain Roots Reflection page
"Dancing Elephants and Floating Continents"

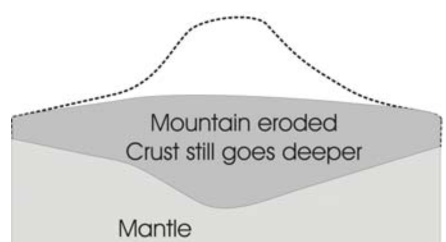
Health and Safety

Clean up all water spills immediately to prevent slipping and accidents.

Lesson Outline

Background

The principle being illustrated in the activity is called isostasy in geological applications, although students are not expected to know this term. Isostasy is very important since it describes a state of dynamic equilibrium within the Earth's outer layers. If a change occurs in the mass of these layers, relative movement occurs to return to the equilibrium state. For example, as tectonic plates collide and rocks are pushed and folded upwards to create mountains, the crust thickens underneath the mountaintops; or when the continents were covered with ice sheets, the crust sank lower in the mantle to compensate for the mass and thickness of ice. After the ice was removed, the crust rose up again. These changes have a considerable influence on the effective sea level around continents.



Isostatic adjustment occurs very slowly, long after the change that has caused the adjustment may have disappeared. Ancient mountain ranges, such as the Grenville Mountains (see page 32 and 33 of "Dancing Elephants and

Floating Continents") can be identified since the thickened crust of the mountain roots still exist, even though the mountaintops have long been eroded. See the diagram illustrating this phenomenon.

Preparation This activity must be done after "Vanishing Mountains." It expands the "Try This" activity on pages 34 of "Dancing Elephants and Floating Continents", principally with the addition of a quantitative approach.

Use objects that have a uniform weight distribution: wood blocks or plastic bottles, but do not add weight to either end. This would change the object's centre of gravity and its buoyancy point will be different. Likewise, objects with an uneven weight distribution will complicate the results. Objects made of the same material but different sizes are ideal, e.g. large and small wooden blocks.

Activity Students measure and record the height above and below the water surface of buoyant objects.

Students use a scatter graph to investigate the relationship of the two variables. Describing a trend may need some additional teaching points depending on the students' mathematic skills. Referring to "density" when categorizing objects is preferred but may not be possible depending on students' prior learning.

Students read page 35 about how it was shown that the Himalayas have roots, and apply their experiences to predict what happens to the root as mountains are eroded.

Close Connect the existence of the mountain roots to the evidence for the Grenville Mountains, which Lithoprobe can identify using their techniques, pages 32 and 33 "Dancing Elephants and Floating Continents" and read aloud at the end of the activity in "Vanishing Mountains".

Sample Student Responses

Describe the trend shown by your graph.

The higher the object is above the water surface, the deeper it is below.

What proportion of objects is above the water compared to below the water: *depends on results*

What pattern can you see for which objects go very deep in the water, in contrast to those that float high on the surface: *dense objects have more under the water than above, less dense objects have less under the water*

How do you think the results would change if we replaced the water with syrup: *objects would float higher on the surface; the syrup holds them up more than water*

Predict what you think might happen when the top of the mountain gets eroded.

There will be a mountain root without a top.

The mountain root will rise up. (This is a correct but advanced concept, referring to isostatic adjustment. It is not expected at this level.)

Mountain Roots

What evidence is there that mountains existed, after they are eroded?

Materials

Water
Large tub or sink
Variety of buoyant objects, e.g. cork, wood, Styrofoam, plastic containers
Ruler
Marker pen
Recording Chart
Mountain Roots Reflections page
"Dancing Elephants and Floating Continents"

Keywords

Crust
Mantle
Buoyancy

Book Connections

Pages 34 and 35

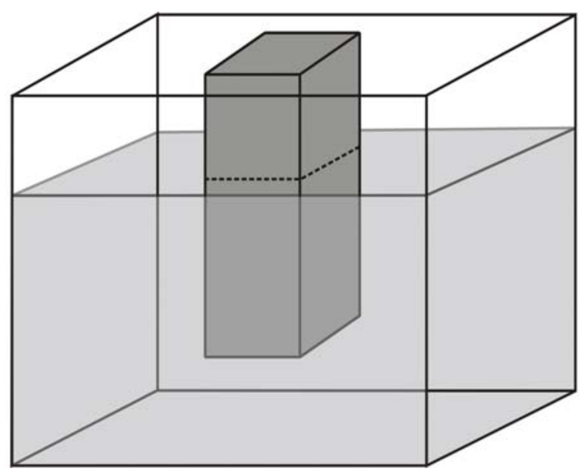
Safety	Any spills of water must be cleaned up immediately to prevent someone slipping.

Instructions

Fill the tub with water to a depth greater than the largest object.

Take one object and float it on the water.

When the object is stable in the water, gently mark a line at water level. Remove the object from the water and measure the portion above and below the water line. Make sure you keep the object the same way up; otherwise your measurements will be incorrect.



Erase any marks you made on the object, and have a partner repeat the measurement. Record your measurements on the Recording Chart.

Repeat for a wide range of objects of different sizes.

Calculate the average for each object’s measurement.

Complete the graph and questions on the Mountain Roots Reflection page.

Recording Chart

Name of Object	Height above water (cm)			Depth below water (cm)		
	Test 1	Test 2	Average	Test 1	Test 2	Average

Copy and expand the chart for more objects if you need.

Plot a scatter graph of the height above the water on the horizontal (x) axis, and depth below the water on the vertical (y) axis.

Mountain Roots: Reflections

Describe the trend shown by your graph.

What proportion of objects is above the water compared to below the water?

What pattern can you see for which objects go very deep in the water, in contrast to those that float high on the surface?

How do you think the results would change if we replaced the water with syrup?

Read the box on page 35 that describes how it was discovered the Himalayas have roots, just like the floating objects.

Predict what you think might happen when the tops of the mountains get eroded.

Time	Grouping	Keywords	Book Connections	Activity
	or Depending on product and assessment method	Cumulative, from all activities	All	

Shaping Our Earth

Main Theme

All the processes discussed in "Dancing Elephants and Floating Continents" produce visible effects on the Earth’s crust. Tectonics, faulting, volcanoes, erosion, and impacts create our physical landscape.

Students’ Tasks

Summarise the processes that shape the Earth’s surface and describe their effects in a presentation to others.

Materials

"Dancing Elephants and Floating Continents"
Supplementary Earth Science resources
Shaping Our Earth student page
Presentation materials of students’ choice

Health and Safety

There are no safety issues in this activity. Students carrying out research on the Internet need to have suitable training and precautions in place for “net proofing.”

Lesson Outline

Background

"Dancing Elephants and Floating Continents" tells a story about the history of Canada’s geology. Each chapter within the story involves earth science processes that shape our Earth and the surface that we see.

Preparation

Intended as a cumulative assessment task, this involves students relating their studies to the wider environment, and restating what they have already experienced to answer a new question.

Alternatively, you may provide the students with a list of the processes to be included and have them identify and explain the process, and describe the surface effects.

Activity

Students will review their activities and reading and use that information to identify and describe the processes that shape the Earth’s surface, and explain their effects on our landscape.

Students are given free choice in how to present their knowledge. Whichever method chosen, the assessment emphasis is on technical content and the ability to communicate technical ideas.

Close

Student products are shared with the group. If desired, an assessment rubric is provided.

Sample Student Responses

Tectonic and surficial processes to be included are:

Plate tectonics
Volcanoes
Earthquakes
Faulting
Subduction
Mountain building
Rifting
Ocean forming
Erosion
Deposition
Meteorite impacts

Assessment

	Excellent	Standard	Needs improvement	Not reaching grade
Displays understanding of the formation of physical features of the Earth's crust	Displays thorough understanding of the formation of physical features of the Earth's crust	Displays general understanding of the formation of physical features of the Earth's crust	Displays some understanding of the formation of physical features of the Earth's crust	Displays limited understanding of the formation of physical features of the Earth's crust
Identifying relevant processes that form physical features of the Earth's crust	Identifies most of the relevant processes that form physical features of the Earth's crust	Identifies a considerable number of processes that form physical features of the Earth's crust	Identifies some relevant processes that form physical features of the Earth's crust	Identifies a few relevant processes that form physical features of the Earth's crust
Communicates with clarity to explain how processes form physical features of the Earth's crust	Communicates with a high degree of clarity to explain how processes form physical features of the Earth's crust	Communicates with considerable clarity to explain how processes form physical features of the Earth's crust	Communicates with moderate clarity to explain how processes form physical features of the Earth's crust	Communicates with limited clarity to explain how processes form physical features of the Earth's crust
Uses visual materials to communicate the processes and effects forming physical features of the Earth's crust	With high degree of success uses visual materials to communicate the processes and effects forming physical features of the Earth's crust	With considerable success uses visual materials to communicate the processes and effects forming physical features of the Earth's crust	With some degree of success uses visual materials to communicate the processes and effects forming physical features of the Earth's crust	With limited success uses visual materials to communicate the processes and effects forming physical features of the Earth's crust

Shaping Our Earth

Why does the surface of the Earth look like it does?

Materials

Presentation materials of your choice

"Dancing Elephants and Floating Continents"

Supplementary research materials

Keywords

Cumulative from all activities

Book Connections

All pages

Safety When you use the Internet do not give out any personal information.

Instructions

"Dancing Elephants and Floating Continents" is "the story of Canada beneath our feet." It's also the story of the landscape that we see around us.

Your task is to describe the processes in the story that shape the Earth's surface and the effects they have on our landscape.

Bonus: name somewhere in Canada that we can see these landscape features.

You will use written and visual information to explain the concepts to your audience. You can use any presentation method; suggestions include:

- Poster
- Illustrated Essay
- Drama Script
- Computer slide show presentation
- Animation
- Model

Your presentation will be assessed on:

- Scientific accuracy in describing the processes that shape the Earth's surface
- Scientific completeness in identifying the processes that shape the Earth's surface
- Use of science language to communication the processes to your audience
- Use of visual material that illustrates and explains the processes to your audience