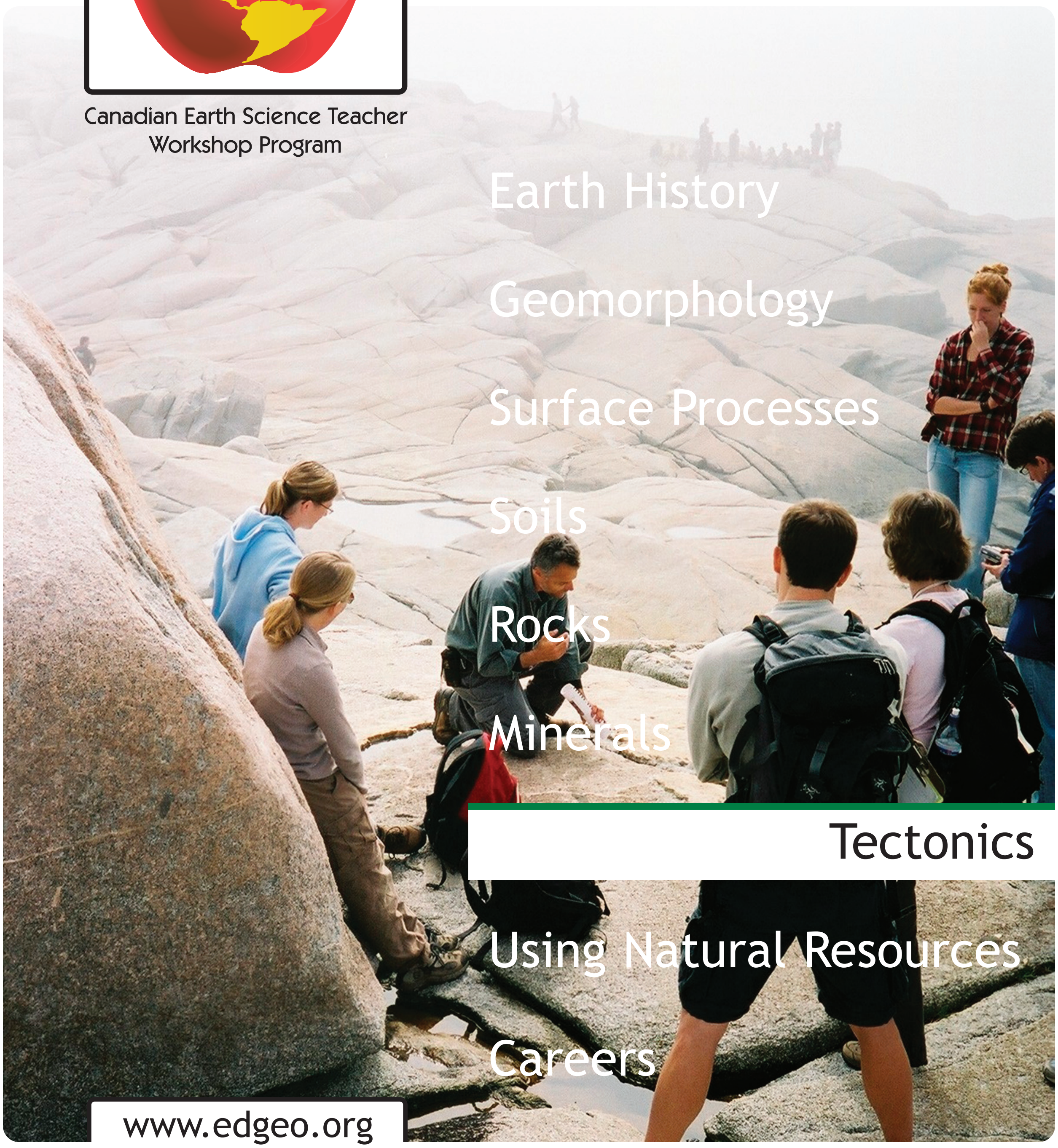
EdGEO

Canadian Earth Science Teacher Workshop Program

Bringing Earth Science to Life



Earth History

Geomorphology

Surface Processes

Soils

Rocks

Minerals

Tectonics

Using Natural Resources

Careers

www.edgeo.org

In partnership with:

Canadian Geological Foundation · Fondation Géologique du Canada · 1968

Canada · Geological Survey · Commission Géologique · 1842

Natural Resources Canada · Ressources naturelles Canada

Mapping Earthquakes and Volcanoes

Students plot the global distribution of earthquakes and volcanic eruptions to see what they reveal about the structure of the Earth's surface.

Explanation

The distribution of volcanoes and earthquakes around the world is not random. Earthquakes and volcanoes are located in similar belts, which correspond to the boundaries between the Earth's plates. The occurrence and locations, as well as the types of volcanoes and earthquakes, are directly related to **plate tectonics**.

Materials

World Map (see Resources)
Coloured pencils
Either: Internet access to global earthquake and volcano information (see Resources for recommended urls); or: overheads made from global earthquake and volcano distribution maps (see Resources)

Caution

Inform students of safety guidelines for Internet use.

Time

Short

Grouping

Individual, pairs

Preparation

Reproduce world maps for the students to plot their data.

Either bookmark the suggested websites or create overheads of global earthquake and volcano distribution maps.

Prompt

Show students photographs or news stories of recent volcanic eruptions or earthquakes. Ask them how likely they think such events are to occur where they live.

Delivery

1. Provide blank world maps to students and access to earthquake and volcano global distribution data.
2. Have students mark the locations of earthquakes in one colour and volcanoes in a contrasting colour.

Questions for Discussion

Which places in the world have the most earthquakes?

Which places in the world have the most volcanoes?

Which places have both earthquake and volcanoes?

Which places have only earthquakes?

Which places have only volcanoes?

From the patterns on the maps, how likely is it that where you live is going to have either an earthquake or volcanic eruption?

What does this evidence suggest about the Earth's surface?

Extensions

Start an ongoing collection of media reports related to earthquakes and volcanoes.

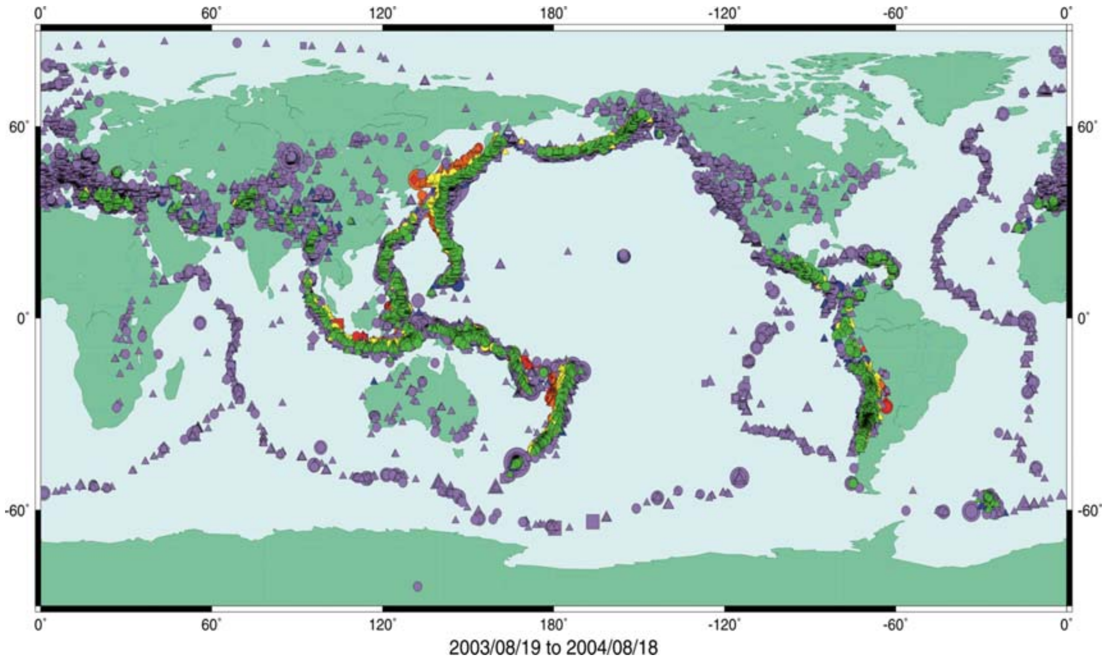
Investigate historical events: location, magnitude, human impact. Good resource sites with Canadian content are: http://earthquakescanada.nrcan.gc.ca/histor/top10-eng.php and http://gsc.nrcan.gc.ca/volcanoes/index_e.php.

Compare earthquake and volcano distribution to maps of tectonic plates (see Tectonic Boundary Processes topic for related activities)

Resources

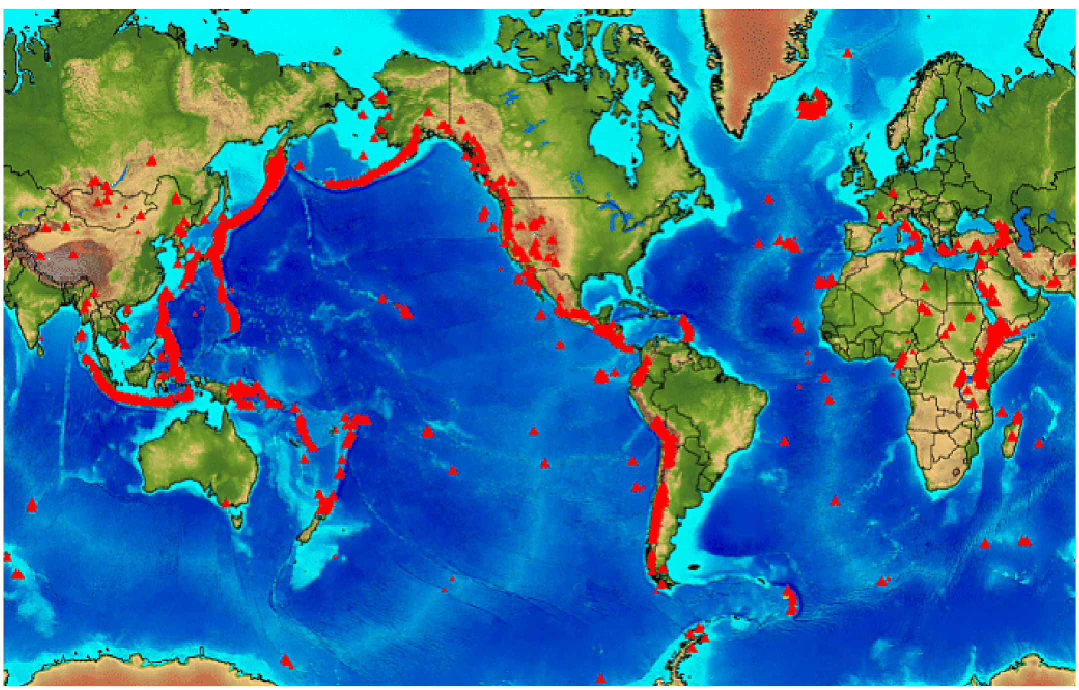
Global Earthquake Distribution

(Source: IRIS Consortium, http://www.iris.edu)



Global Volcano Distribution

(Source: Smithsonian Institution, Global Volcanism Program, http://www.volcano.si.edu)



World Map

Mapping Surface Movement

Students map the distance and direction of surface movement at various locations around the Earth.

Explanation

Geological evidence shows that our present-day continents were once part of a single, giant land mass, which Earth scientists have named Pangea, and that there have been repeating cycles of continents splitting apart, moving together, joining and dividing again over the millennia. The continents that we know today have not always been the same, but are a result of these changes over time. The evidence can be found in fragments of one continent attached to another and by the existence of ancient, inactive plate boundaries within continents.

We now can precisely monitor surface movement using a network of satellites recording GPS (global positioning satellite) data transmitted to them from permanent GPS stations on the ground. The orbiting satellites create a fixed background, and we can tell how much and in what direction the ground stations move within this framework. This GPS data is primary evidence that helps us understand how the Earth's surface is moving. The data given for the activity is an average for each station over approximately the last 10 years.

It is important to know that plate motion is not in straight lines. It is most easily described as sweeping curves. As well, the directional arrows that the students will plot on the map are not constant over geological time. As a result of this activity students will observe that the surface of the Earth is moving as large sections and in opposing directions.

Materials

World Map (see Resources)
Student Activity Page
Coloured pencils
Protractor
Ruler
Atlas

Caution

None

Time

Medium

Mapping Surface Movement

Grouping

Individual, pairs

Preparation

Reproduce Student Activity Page and maps on which they will plot the data.

Prompt

Show photographs or news stories of recent earthquakes. Ask students what they think is causing these earthquakes to happen.

Delivery

1. Distribute materials and describe the task. Show students how to measure a bearing from north using the protractor:
   a. Place the centre of the protractor on the city's location.
   b. Orient the zero line of the protractor to compass north on the map.
   c. Face the protractor left if the direction of motion is west of north, or right if it is east of north.
   d. Mark the correct angle from zero (north).
2. Allow students time to complete their maps and answer the questions on the student page.
3. As a whole group, discuss the patterns seen in the arrows on the maps. Depending on their prior knowledge, you may or may not refer to tectonic plates.

Questions for Discussion

What might be happening where the surface sections are moving together? Apart?

Where are the fixed points that we are comparing the surface motion to?

How reasonable is it to assume that the plates would move at the same speed throughout time?

Extensions

Download additional data from the NASA/JPL website in digital form and expand the map coverage: http://sideshow.jpl.nasa.gov/mbh/series.html

Compare the GPS motions to maps of the tectonic plates (see Tectonic Boundary Processes topic for related activities)

Mapping Surface Movement

You are going to map the distance and direction of the movement of the Earth's surface at various locations around the world.

Materials

World map
Coloured pencils
Protractor
Ruler
Atlas

Instructions

1. Use the atlas to find the location of each city on the data chart.
2. Draw a small dot on your world map to mark each city.
3. Draw a line starting from the dot to show how that city moved in one year, using the data given in the chart. Use the protractor and ruler to make the line the correct length and angle.

Questions

1. What is the greatest distance moved by any of the cities in the last year?
2. Which compass direction (north, south, east or west) is the closest to the way each of the continents are moving?

Data

This chart provides GPS data from ground stations around the world showing the average distance moved by each station in 1 year and the direction it is moving. Note: the direction is given as degrees either east or west from north.

Location	Distance: mm per year	Direction: Degrees from N
Auckland, New Zealand	40	5 E
Bogotá, Columbia	13	2 E
Buenos Aires, Argentina	12	10 W
Canberra, Australia	58	18 E
Cape Town, South Africa	21	36 E
Denver, USA	17	103 W
Detroit, USA	17	87 W
Easter Island, Pacifica	67	93 W
Fairbanks, USA	23	159 W
Guam, Micronesia	11	77 W
Hawaii, USA	72	60 W
Lagos, Nigeria	13	34 W
Oslo, Norway	21	50 E
Pittsburgh, USA	16	81 W
Santiago, Chile	25	50 E
Seattle, USA	14	131 W
St Johns, Canada	19	51 W
Ulaanbaatar, Mongolia	25	100 E
Vladivostok, Russia	27	121 E
Yellowknife, Canada	21	125 W

Source: NASA and the Jet Propulsion Laboratory http://sideshow.jpl.nasa.gov/mbh/series.html

World Map

Continental Jigsaw Puzzle

Students use geological evidence (location of fossils and ice-flow direction) to reconstruct the positions of today's continents 200 million years ago.

Explanation

If you look at a map of the world, you can see that if you closed the Atlantic Ocean, the western bulge of Africa would fit nicely into the eastern side of the Americas, stretching from Nova Scotia to Brazil – much like a giant jigsaw puzzle. This, in fact, was one of the first pieces of evidence that the configuration of the Earth's tectonic plates was not always as it is today.

Other evidence suggesting that the continents have "drifted" over time is that the same fossils and the same ancient glacial deposits are found in continents now separated by vast oceans. In this activity, we are going to look at the today's continents of the Southern Hemisphere to reconstruct the supercontinent Gondwanaland of 200 million years ago.

Materials

Ice flow and fossil distribution maps (see Resources)
Scissors

Caution

None

Time

Short

Grouping

Individual, pairs

Preparation

Optional: Cut out and laminate the continental pieces showing ice direction and fossil distribution for repeated use.

Prompt

Brainstorm with students about the kinds of animals and plants that are found in Canada. Ask them if they would find the same mix of plants and animals in other countries? For example, polar bears do not live in Africa, and giraffes are not found in Canada. Each continent around the world has its own specialized groups of animals and plants.

Delivery

1. Distribute ice flow maps to half of the class, and fossil distribution maps to the other. Describe that the maps show where Earth scientists have found the same fossils, or the same age and type of ice sheet features.
2. Discuss that it would have been impossible for such evidence to exist on now widely separated continents if they had not at one time been connected.
3. Direct students to cut out the continent pieces on the maps and fit them together to form a single land mass based on the evidence provided by ice flow directions and fossil distribution.
4. Have representatives from each half of the class share their completed maps.
5. Optional: Distribute additional maps so that each group completes both the fossil and ice flow matching exercises.

Questions for Discussion

Do the two pieces of evidence lead to the same conclusion about the continent positions 200 million years ago?

What might have happened to produce the pattern we see today?

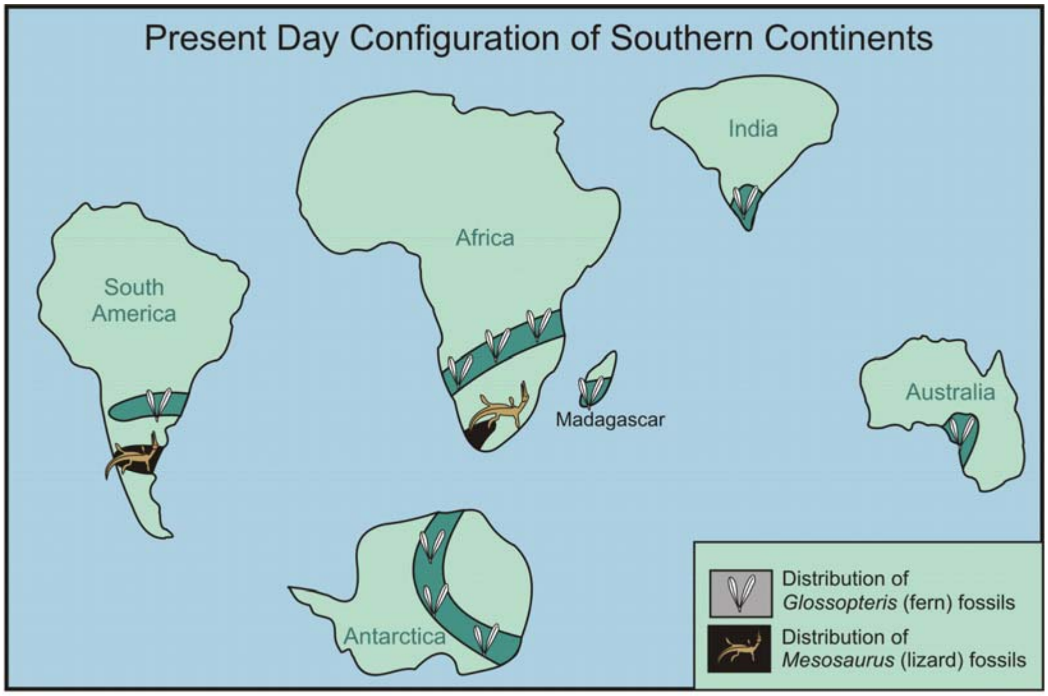
Extension

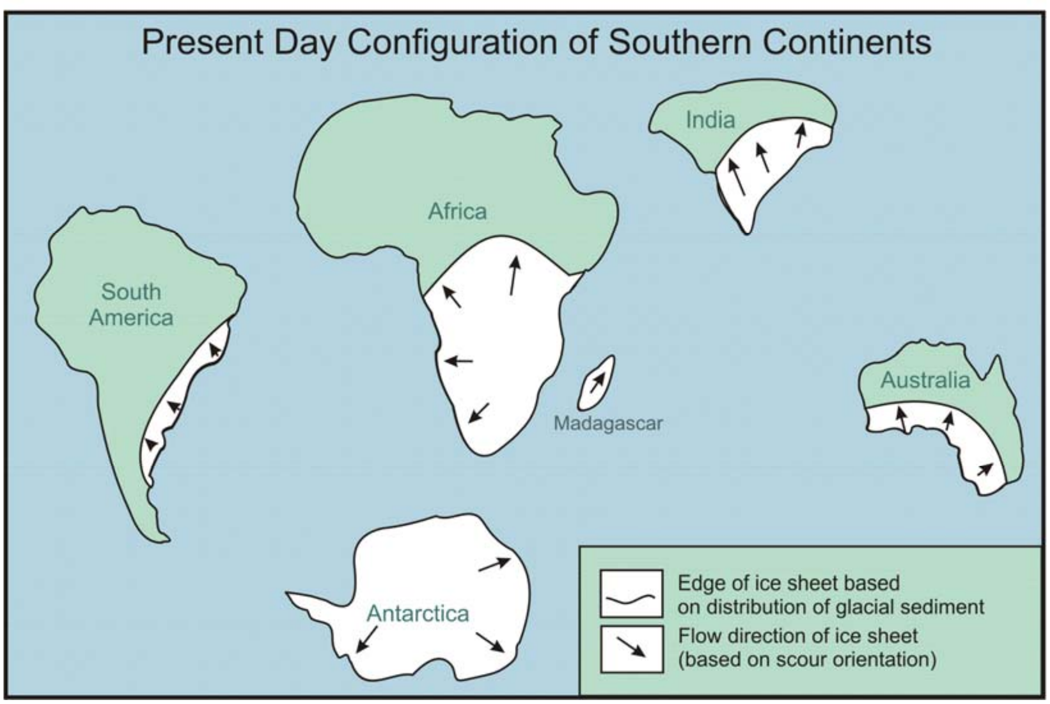
Visit the PALEOMAP Project for more examples of continent positions, including animations and teacher materials: http://www.scotese.com

Resources

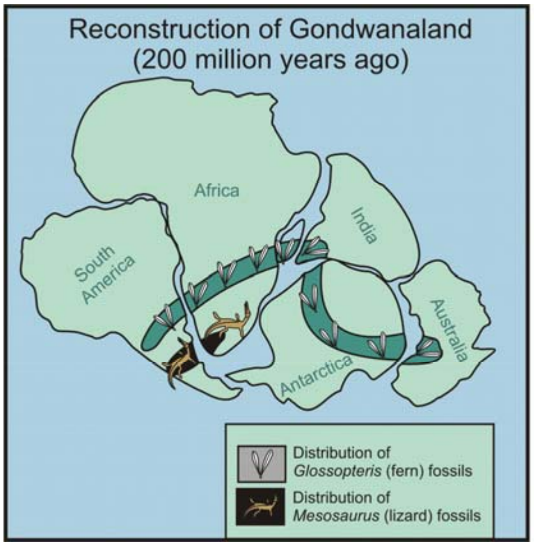
Ice flow and fossil distribution maps

(Source: U.S. Geological Survey)





Solution


Reconstruction of Gondwanaland
(200 million years ago)
Africa
South America
India
Antarctica
Australia
Distribution of Glossopteris (fern) fossils
Distribution of Mesosaurus (lizard) fossils

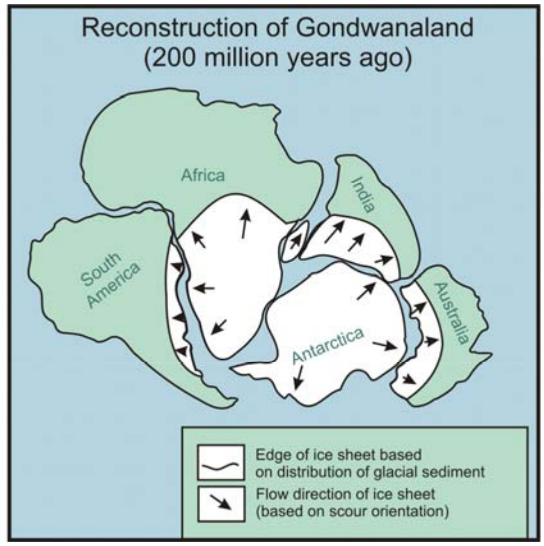

Reconstruction of Gondwanaland
(200 million years ago)
Africa
South America
India
Antarctica
Australia
Edge of ice sheet based on distribution of glacial sediment
Flow direction of ice sheet (based on scour orientation)

Plate Tectonics Flipbook

Students colour, cut out and assemble a series of maps showing the continents' positions and movement following the breakup of Pangea to present day.

Explanation

Geological evidence such as fossil distributions, rock types, paleomagnetism and ice flow direction has enabled Earth scientists to map the movement of the continents over time.

What the geological evidence shows is that our present-day continents were once part of a single, giant land mass, which Earth scientists have named Pangea, and that there have been repeating cycles of continents splitting apart, moving together, joining and dividing again. Pangea split into Gondwanaland and Laurasia over 200 million years ago, and further splitting apart has resulted in the present-day configuration of the continents, which are still on the move.

Materials

Flipbook pages (see Resources)
Scissors
Stapler
Coloured pencils
Student Activity Page

Caution

Safe use of scissors and stapler is necessary.

Time

Medium

Grouping

Individual, pairs

Preparation

Reproduce flipbook pages and Student Activity Page.

Prompt

Show students an illustration of dinosaurs in a tropical environment. Ask them why they think we find dinosaur fossils in Canada, especially Alberta, where the climate is not tropical. Accept any response at this time.

Delivery

1. Distribute the materials, flipbook pages and student activity pages, and allow time for colouring and construction.
2. Discuss as a group what students see as they flip the book pages.

Questions for Discussion

What started to happen about 200 million years ago?

What could be making the continents move?

What effects would this movement have on the animals and plants that lived there?

Extension

Visit the PALEOMAP Project for more examples of continent positions, including animations and teacher materials: http://www.scotese.com

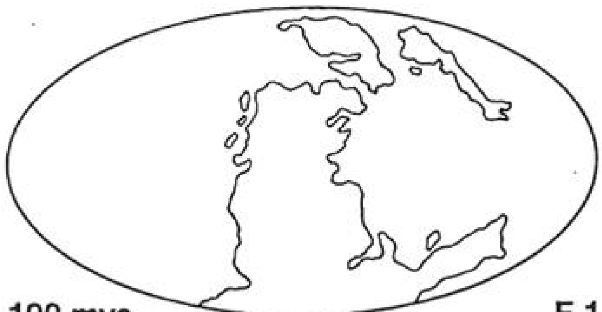
You are going to find out how the continents have moved and altered after the breakup of the supercontinent Pangea to present-day.

Materials

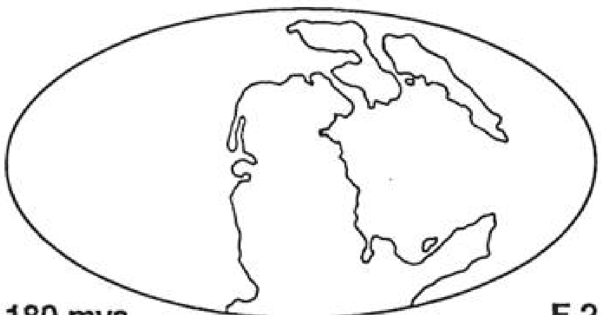
Flipbook pages
Scissors
Stapler
Coloured pencils

Instructions

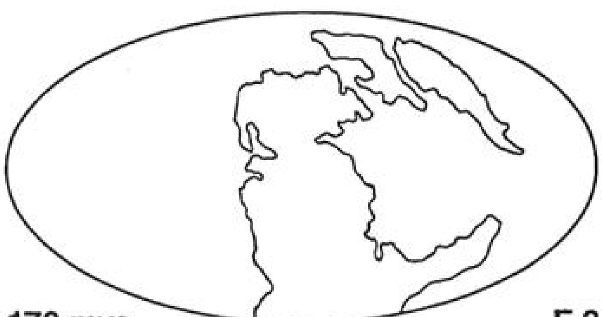
1. On map F20, shade North America in one colour.
2. Locate and colour what best appears to be North America on maps F19, F18 and so on back to map F1, using the same colour on each map. When you cannot decide where the edges of North America are, leave it uncoloured.
3. Repeat for the other continents, using different colours for each.
4. Cut out the maps along the dotted lines.
5. Lay the maps on top of each other in order, starting with F1 at the top and ending with F20 at the bottom.
6. Staple along the left-hand side to hold the pile together.
7. Flip through pages using the right-hand edge and watch how the positions of the continents have changed in the last 190 million years.



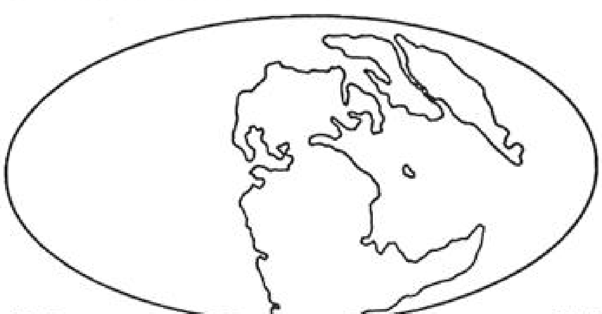
190 mya F 1



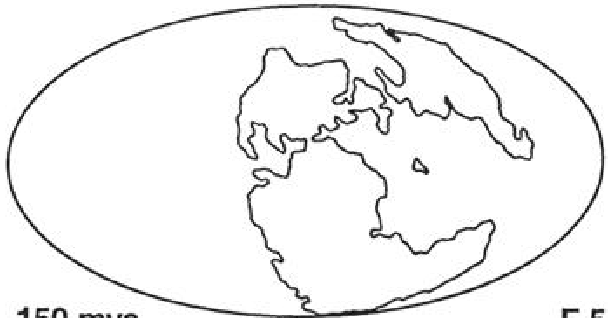
180 mya F 2



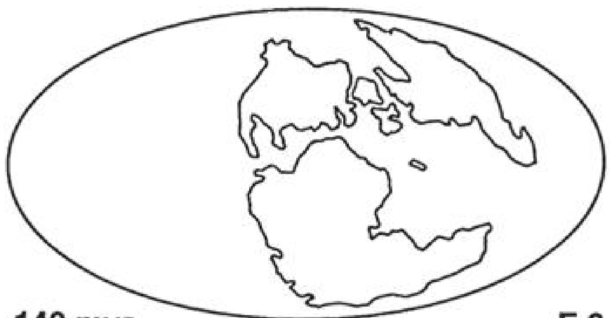
170 mya F 3



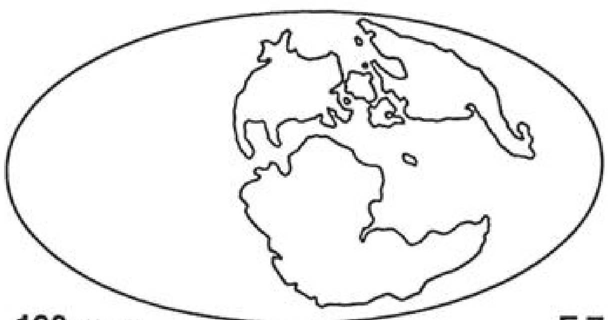
160 mya F 4



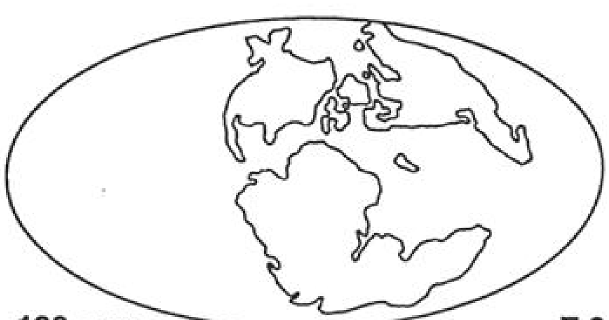
150 mya F 5



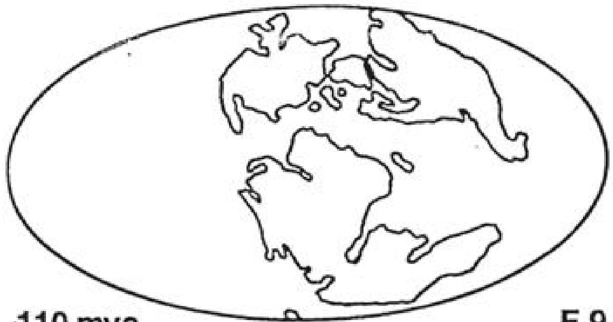
140 mya F 6



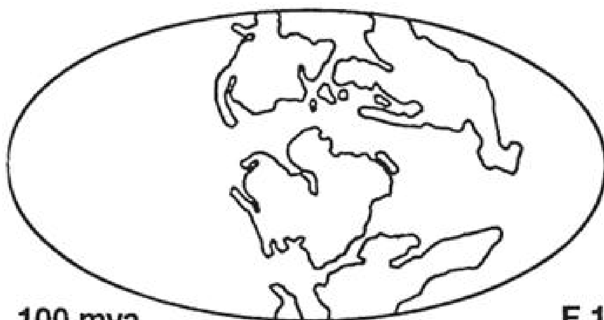
130 mya F 7



120 mya F 8



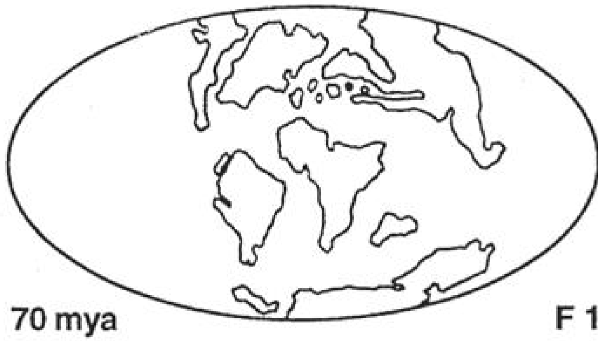
110 mya F 9



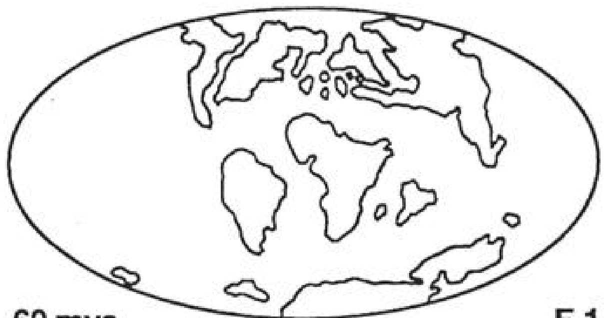
100 mya F 10

90 mya F 11

80 mya F 12



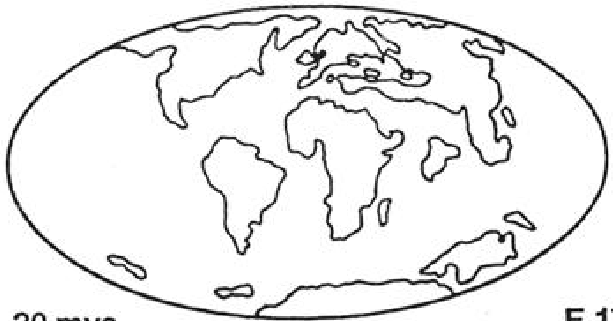
70 mya F 13



60 mya F 14

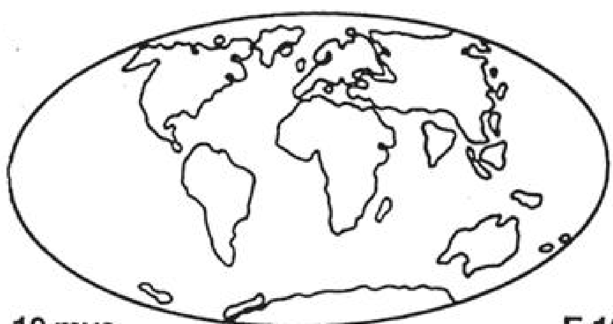
50 mya F 15

40 mya F 16

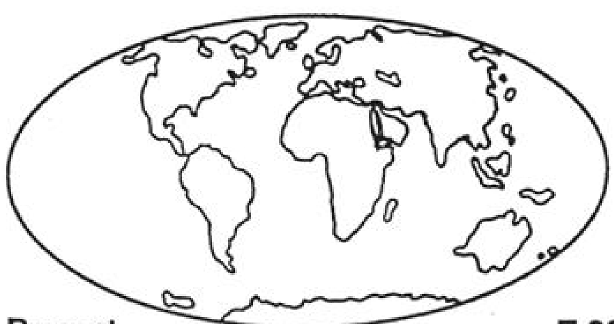


30 mya F 17

20 mya F 18



10 mya F 19



Present F 20

Time Travel to Past Continents

Students visualize ancient environments from descriptions provided and create a tourism flyer for a time-travel trip to an ancient supercontinent.

Explanation

The positions and shapes of today's continents have been in a state of constant change over geological time. The geological evidence shows that our present-day continents were once part of ancient supercontinents stretching back over 2 billion years. As a result of repeating cycles of splitting apart, moving together, joining and dividing again, Canada is made up of geological parts from many, often widely contrasting, ancient environments. The precise details of the surface features of these ancient supercontinents are not well defined by the rock and fossil evidence of their existence, so in this activity there is considerable scope for imagination and interpretation.

Materials

Destination Cards (see Resources)
Student Activity Page
Art materials

Caution

None

Time

Medium

Grouping

Individual, pairs

Preparation

Reproduce destination cards and cut into separate pieces.

Prompt

Show students a selection of tourism flyers for exotic locations. Ask them what information they would like to have if they were planning a trip.

Delivery

1. Distribute one destination card to each group. Students should not know the descriptions of the other destinations until the sharing session.
2. Encourage students to carry out independent research of their destination and the geological era it dates back to, in order to supplement the basic information on the cards.
3. Allow creative time for students to prepare their tourism flyer.
4. Have students share their flyer with the group.

Question for Discussion

What changes have occurred to Canada through geological time?

Extension

Read the children's book "Dancing Elephants and Floating Continents." Additional information about the book and supporting teaching material can be obtained from http://lithoprobe.ca

Resources

Destination Cards

Slave	Rodinia
Age: 2100 million years ago Climate: very hot in the day, freezing at night Life forms: single-cell organisms with no nucleus Canada's landscape: Huge ocean containing odd-shaped islands and volcanoes Thin atmosphere of toxic gases Meteorites making craters	Age: 1100 million years ago Climate: like Antarctica today, continent centred on the south pole Life forms: microscopic algae, multi-cell organisms Canada's landscape: Grenville mountains, larger than the Himalayas, between present-day Mexico and Labrador
Laurentia	**Pangea**
Age: 500 million years ago Climate: similar to Canada today Life forms: "Cambrian explosion" oceans full of unusual creatures, nothing like today's. Some similar to worms, jellyfish, beetles, sea slugs. No fish or land plants. Canada's landscape: Iapetus ocean to the south and east, a shallow sea to the north. Subduction and volcanoes off present-day east coast	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's landscape: Appalachian mountains on present-day east coast Oceans shrinking on west, islands joining to Canada

Source: Lithoprobe

Time Travel to Past Continents

You are the inventor of a time-travel machine and are looking for customers. You need to prepare a flyer to promote a "Trip of a Lifetime" eco-adventure that will take travellers back in time in Canada, when it was part of one of the supercontinents in the Earth's geological history.

Materials

Destination Card
Art materials

Instructions

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

Decide what you will need to promote to encourage travellers to take your eco-adventure. For example, you will have to tell them: What they will see. What the adventure will be. Where they would visit and why it would be exciting. What they will need to bring with them.

Your travel group will follow zero-impact tourism rules: take only pictures and leave only footprints. Your travellers can only take with them what they can fit in the time machine.

Based on this information, prepare your one-page tourist flyer, using pictures and words to attract people to visit the ancient world you are promoting.

Display your tourist flyer 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.

Convection

Students watch a demonstration of convection currents with hot and cold water, and use this to explain tectonic plate motion in the Earth.

Explanation

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 the effect of plate motion. Other processes that may contribute to fuelling plate motion relate to the physical properties of the plates such as temperature and density, and their different behaviours due to gravity caused by variations in these physical properties.

Materials

Large transparent container (e.g. aquarium, large glass jar)
Hot water
Cold water
Small container with lid
Food colouring
Structure of Earth image (see Resources)
Convection in Earth image (see Resources)
Student Activity Page
Optional: Lava Lamp

Caution

Clean up any spills immediately.

Time

Short

Grouping

Whole group demonstration

Preparation

Reproduce Student Activity Page for each student. Optional: prepare and provide a keyword list in advance.

Prompt

Revisit any of the activities looking at motion of the continents or evidence for plate tectonics. Remind students of their explanations of why these phenomena are observed.

Delivery

Set up a large transparent container filled with cold water in a place where the whole group can see it.

Distribute the Student Activity Page to each student.

Follow the script and instructions in the Resource section below for the demonstration.

Extensions

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 water sinks.

Alternative methods for demonstrating convection include:

- Heating dried herbs (basil, thyme) in cooking oil in a glass container on a hot plate.
- Using a dropper to place small amounts of hot and cold liquid into the water in the tank.
- Adding cold milk to hot water in the tank.
- Placing foam pieces on the surface of water being heated.

Resources

Script and Instructions

Teacher: I am going to show you something very important about our Earth. As you watch and listen, note down on your listening sheet any keywords or ideas that you think are important. We've seen that earthquakes and volcanoes happen in the bands around the world that divide the Earth's crust into separate regions. Scientists call those regions "tectonic plates".

We've also seen evidence that the continents have been continuously moving through geological time, and we've tried to imagine what mysterious forces might be pushing and pulling the Earth's crust, closing oceans, building mountains and more. Now let's see what Earth scientists think is making these tectonic plates move.

[Instruction: Fill the small container with hot water, add food colouring to strongly colour it, and put on the lid.]

Teacher: I've filled this big container with cold water, and in this little one is hot water. I've also added 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: Place the container of hot water at the bottom of the large cold water tank. Quickly take the lid off the hot water container 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 in the container, in the heater the hot air rises. 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 put on the lid. Place it back on the bottom of the large cold-water container, quickly taking off the lid.]

Students: It doesn't rise up this time

Teacher: For convection to work there must be differences in temperature. Hot water rises through cold water. So what does this tell us about the moving plates on the Earth's surface? 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 the 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 tectonic plates on the top 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?

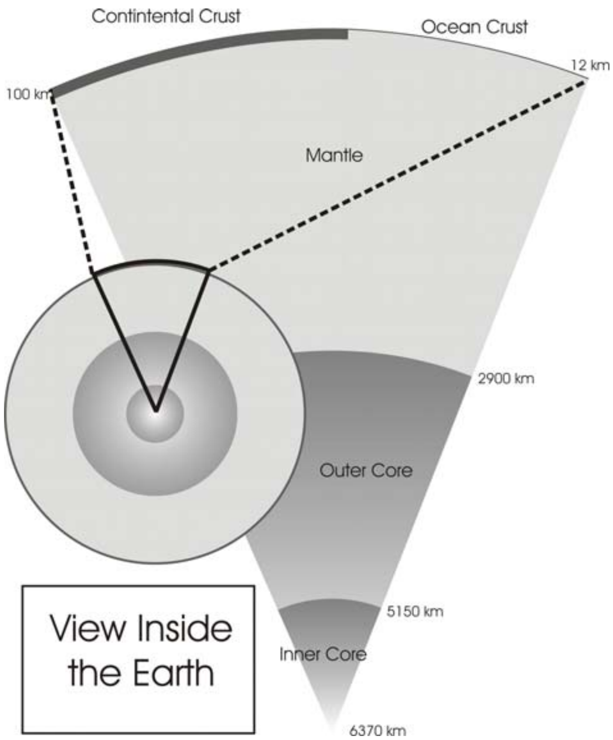
Students: Where the bulb is in the base.

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.

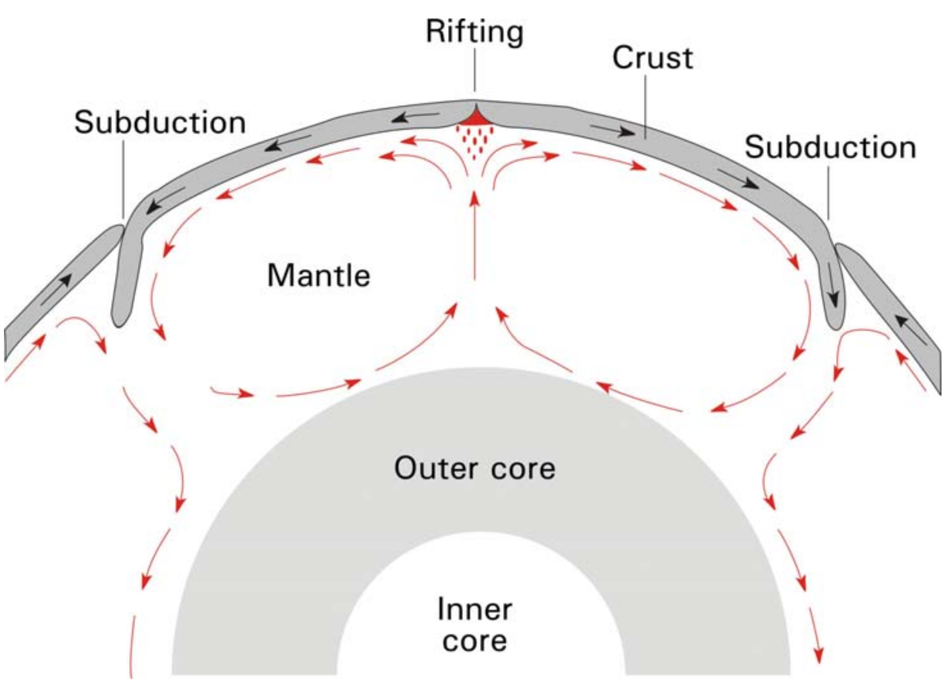
Teacher: As the bubbles warm up they rise up the lamp, and sink again as they cool down. This is just like convection in the water, and in the Earth's mantle.

Structure of the Earth



Convection in the Earth

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



Listening Sheet

1. As you listen and watch the demonstration, note down any keywords and ideas that you think might be important to understanding plate tectonic movement in the Earth.

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

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

The Earth as an Egg

Students compare the inside of a hard-boiled egg to the layers of the Earth.

Explanation

Planet Earth weighs about 6 x 10^{21} (6 sextillion) tonnes. When Earth formed, its outer layer cooled rapidly and a crust formed. Gravity caused the heavier elements (e.g. iron and nickel) to settle toward the centre of the Earth where they remain. The three main zones that make up our planet's interior are:

- The **crust**, which is made up of solid rock and a thin layer (centimetres to metres) of soil. The crust is approximately 5-10 km thick under the oceans, an average of 40 km thick where there are continents, and up to 100 km beneath mountains.
- The **mantle**, which consists of semi-solid rock and is 2900 km thick. The temperature is around 870°C where the mantle meets the crust, and it gets progressively hotter the deeper down it goes. Parts of the mantle are in motion as a result of convection currents
- The **core**, which has an outer core and an inner core. The outer core is 2200 km thick and is made up of liquid iron and nickel at a temperature of 2200°C. The inner core is 1275 km to the centre of the Earth and is a mixture of solid iron/nickel at a temperature of 5000 to 7000°C.

Materials

Overheads: View inside the Earth and cut-away view of Earth (see Resources)
For each group:
Hard-boiled egg
Knife
Marker pen

Caution

Choose a responsible person to cut the eggs in half.

Time

Short

Grouping

Pairs, small groups

The Earth as an Egg

Preparation

Prepare one hard-boiled egg for each student group and cool completely.

Prompt

Hold up a rubber ball or globe. Explain that our Earth is shaped like a ball, and ask students to draw a picture of what they think the inside of the Earth looks like. These sketches are very useful to assess prior knowledge and conceptions about the Earth. Prompt them to consider what is inside the Earth, and also how large these things are.

Delivery

1. Give a hard-boiled egg to each group.
2. Explain that the Earth is very much like an egg. The outer layer is thin and can be cracked easily. Tell students to lightly crack the shell of their egg, but do not peel the shell off.
3. Explain that the cracks in the shell are similar to faults in the Earth's crust.
4. Carefully cut the eggs in half, keeping as much shell on as possible.
5. With a marker, draw a circle about the size of a pea in the centre of the yolk.
6. Explain that the circle represents the solid inner core of the Earth. The rest of the yolk is the outer core, which is a liquid. The egg white is the semi-solid mantle, and the shell is the crust. The relative proportions between the shell, white and yolk are a fairly accurate representation of the Earth's layers.
7. Display a cross-section of the Earth's layers to compare with the egg model.

Questions for Discussion

Which is the thinnest layer of the Earth?

How is the egg model like the Earth?

How is the egg model not like the Earth?

How did the egg model compare to your sketch?

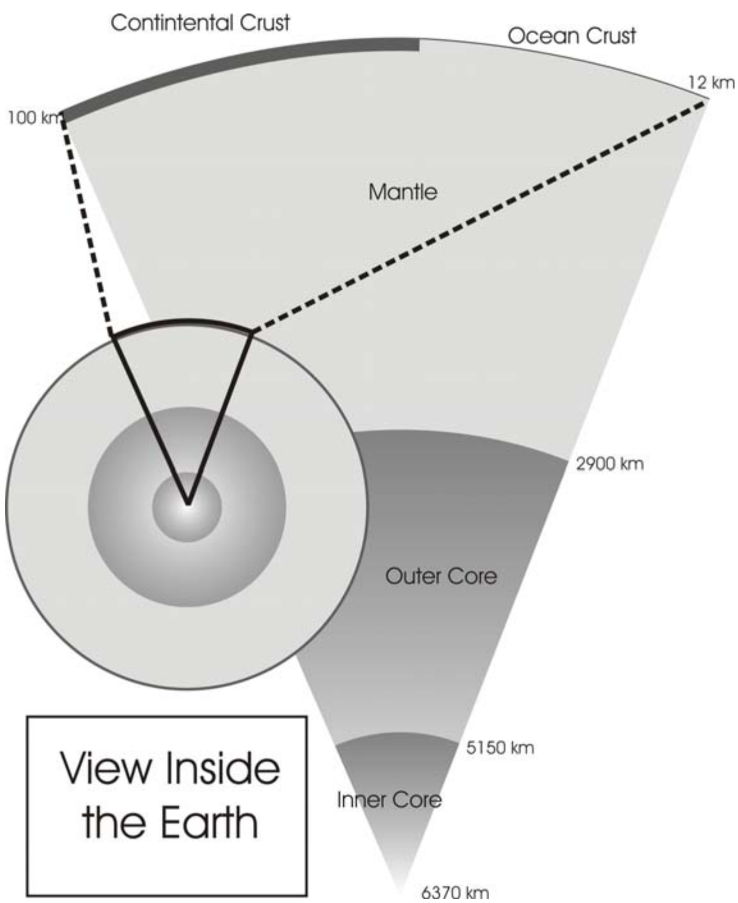
How much of the Earth is liquid?

Extensions

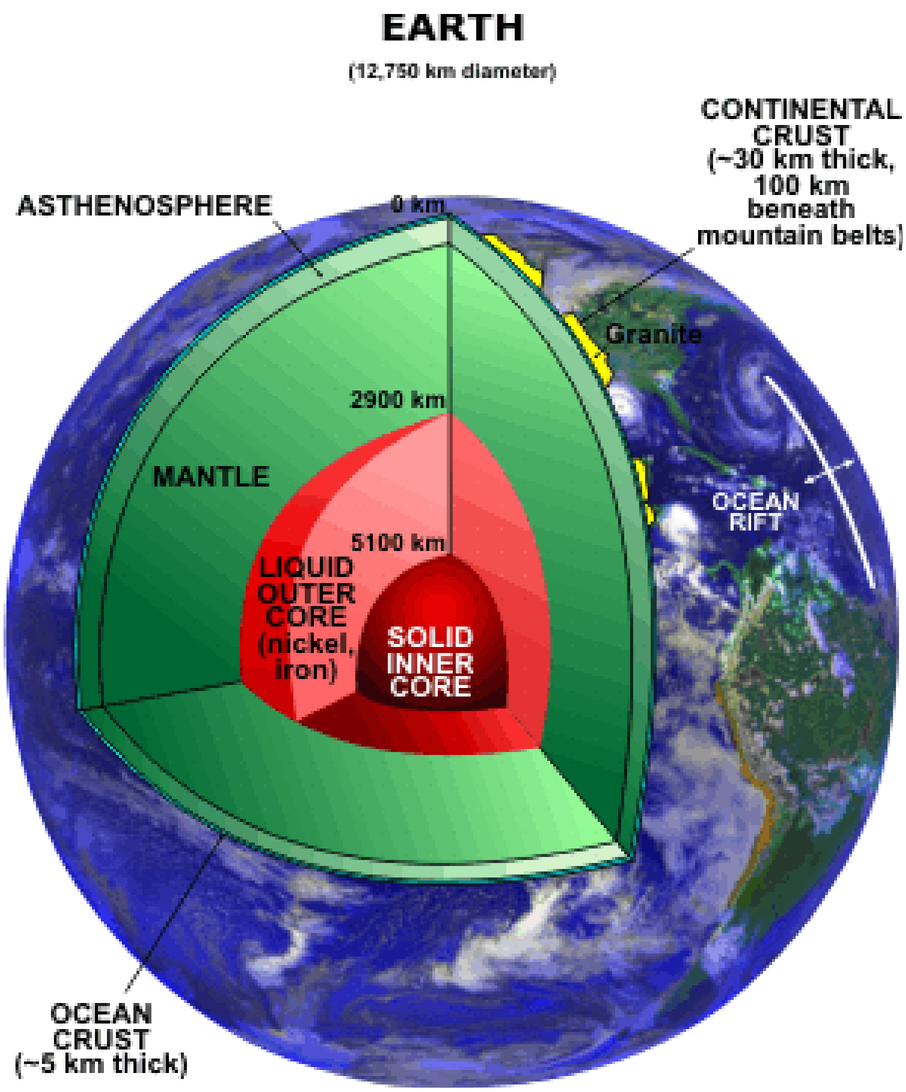
Devise alternative analogies for the internal structure of the Earth.

Build a scale model of the layers (see Scale Model of Earth's Layers activity)

Resources



The Earth as an Egg



An Edible Earth

Students create a model of the Earth's interior using hard candy, marshmallows, Rice Krispie recipe and chocolate chips to represent the different layers.

Explanation

Planet Earth weighs about 6 x 10^{21} (6 sextillion) tonnes. When Earth formed, its outer layer cooled rapidly and a crust formed. Gravity caused the heavier elements (e.g. iron and nickel) to settle toward the centre of the Earth where they remain. The three main zones that make up our planet's interior are:

- The **crust**, which is made up of solid rock and a thin layer (centimetres to metres) of soil. The crust is approximately 5-10 km thick under the oceans, an average of 40 km thick where there are continents, and up to 100 km beneath mountains.
- The **mantle**, which consists of semi-solid rock and is 2900 km thick. The temperature is around 870°C where the mantle meets the crust, and it gets progressively hotter the deeper down it goes. Parts of the mantle are in motion as a result of convection currents
- The **core**, which has an outer core and an inner core. The outer core is 2200 km thick and is made up of liquid iron and nickel at a temperature of 2200°C. The inner core is 1275 km to the centre of the Earth and is a mixture of solid iron/nickel at a temperature of 5000 to 7000°C.

Materials

Wax paper
Large spoon
Either: Microwave and large and small microwavable bowls
Or: Hotplate and large and small pots
Access to freezer
Tray
1 small bowl per group
Sharp knife

Inner and Outer Core:
1 hard, spherical candy per student, e.g. jawbreaker
1 large marshmallow per model

Mantle using Rice Krispie Recipe (enough for 5-7 models):
50 ml margarine or butter
250 g marshmallows

2 ml vanilla extract
1.5 L Rice Krispie cereal

Crust:
Chocolate Chips

Caution

A responsible person must do all heating, melting and cutting.

Time

Medium

Grouping

Pairs

Preparation

The Rice Krispie mantle mix can be prepared slightly ahead of time, but needs to still be mouldable for the activity.

Prompt

Hold up a rubber ball or globe. Explain that our Earth is like a ball, and ask students to draw a picture of what they think the inside of the Earth looks like. These sketches are very useful to assess prior knowledge and conceptions about the Earth. Prompt them to consider what is inside the Earth, and also how large these things are.

Delivery

1. Students: Working in pairs, place a marshmallow on a sheet of wax paper, and poke a hole in the middle of the marshmallow.
2. Students: Insert one candy (solid inner core) into the hole and fold the marshmallow (outer core) around it so it completely surrounds the candy. Place the core on the sheet of wax paper. One student is to save their candy until the Earth model is cut in half.
3. Teacher:
    a. Melt margarine in large container using either microwave or hotplate. Add marshmallows and stir until completely melted. Remove from heat.
    b. Stir in vanilla. Stir in Rice Krispies cereal until well coated.

   c. Divide the mixture evenly between the student pairs onto their wax paper.
   d. Allow to cool for a couple of minutes.

4. Students: pack mixture tightly around the inner/outer core to form a ball.
5. Students: Put the models on a tray lined with wax paper, label, and chill in the freezer for about 15 minutes.
6. Teacher: melt chocolate chips using microwave or hotplate and divide into small bowls.
7. Students: take models out of freezer and carefully roll them in melted chocolate. Make sure the chocolate covers the whole model in a thin layer.
8. Students: Chill models for another 5-10 minutes until the chocolate hardens.
9. Teacher: Cut the model Earth in half.
10. Students: Add the remaining candy to the half without one. Each student gets half of the Earth to evaluate and eat.

Questions for Discussion

Which is the thinnest layer of the Earth?

How is the model like the Earth?

How is the model not like the Earth?

How did the candy model compare to your sketch?

Extensions

Devise alternative analogies for the internal structure of the Earth.

Build a scale model of the layers (see Scale Model of Earth's Layers activity)

Scale Model of Earth's Layers

Students design and build a scale model of the Earth's interior layers.

Explanation

Planet Earth weighs about 6 x 10^{21} (6 sextillion) tonnes. When Earth formed, its outer layer cooled rapidly and a crust formed. Gravity caused the heavier elements (e.g. iron and nickel) to settle toward the centre of the Earth where they remain. The three main zones that make up our planet's interior are:

- The **crust**, which is made up of solid rock and a thin layer (centimetres to metres) of soil. The crust is approximately 5-10 km thick under the oceans, an average of 40 km thick where there are continents, and up to 100 km beneath mountains.
- The **mantle**, which consists of semi-solid rock and is 2900 km thick. The temperature is around 870°C where the mantle meets the crust, and it gets progressively hotter the deeper down it goes. Parts of the mantle are in motion as a result of convection currents
- The **core**, which has an outer core and an inner core. The outer core is 2200 km thick and is made up of liquid iron and nickel at a temperature of 2200°C. The inner core is 1275 km to the centre of the Earth and is a mixture of solid iron/nickel at a temperature of 5000 to 7000°C.

It is important to bear in mind that the depths given above for the different layers are not definitive. The Earth is not a perfect sphere, and there is considerable variation in its lateral internal structure, mostly due to plate tectonics. Underneath the continents, the thickness of the Earth's crust depends on the height of the land, being thickest under mountains.

There are also layers in the Earth that have different physical properties. The mantle has a strong, rigid upper layer that together with the crust makes up the **lithosphere**, which averages between 60 and 140 km thick. The lithosphere is broken into 10 to 12 major tectonic plates, and they move across the surface of the Earth. Continents are like rafts embedded in the lithosphere.

In the mantle under the lithosphere lies the **asthenosphere,** which is much weaker and hotter than the lithosphere because it is partially molten. The asthenosphere has the consistency of toothpaste and moves slowly under pressure, enabling, in turn, the tectonic plates of the lithosphere above to move around.

Scale Model of Earth’s Layers

Materials

Earth’s Layers data table (see Resources)
Various construction materials as per student design: string, card, markers

Caution

None

Time

Medium

Grouping

Pairs, small groups

Preparation

Reproduce the Earth’s layers data table. Collect an assortment of art materials for the students to choose from for their models.

Prompt

Hold up a rubber ball or globe. Explain that our Earth is like a ball, and ask students to draw a picture of what they think the inside of the Earth looks like. These sketches are very useful to assess prior knowledge and conceptions about the Earth. Prompt them to consider what is inside the Earth, and also how large these things are.

Delivery

1. Provide students with the Earth layers data table, which includes the scale for models that are based on either 7 metres or 1 metre. Encourage students to use their own scales to suit their designs and materials.
2. Allow students time to design and create a model. Suggestions include a long tape marked into the different layers, or a circular picture using large sheets of paper.
3. Display and share the different models.

Questions for Discussion

How did your picture compare to your model?

What is the thinnest layer of the Earth? The thickest?

Extension

Investigate how deep mines are, and how we know about the Earth's layers.

Resources

Earth's Layers

Layer	Average depth to base of layer from surface		Scale along a 10 metre model	Scale along a 1 metre model
Crust	Oceanic	5 km	0.5 cm	0.05 cm
	Continental	40 km	4 cm	0.4 cm
Lithosphere	100 km		10 cm	1 cm
Mantle	2900 km		290 cm	29 cm
Outer core	5100 km		510 cm	51 cm
Core	6375 km (centre of Earth)		637 cm	63.7 cm

Modelling Tectonic Boundaries

Students investigate and model convergent, divergent and transform plate boundaries using foam sheets.

Explanation

The tectonic plates on the Earth's surface move in different directions, and the boundaries between them are very dynamic regions. Indeed, most of the world's earthquakes and volcanoes are the result of the movement of these plates (**plate tectonics**). The three types of plate boundaries are:

Divergent: The lithosphere is being stretched and pulled apart, so the plates on each side of the boundary move apart and magma from below wells up into the gaps. As a result of this stretching and the rising magma you get:

- Shallow-focus earthquakes
- Extreme topography of long, high ridges, with deep rift valleys or fissures in the crust in between
- Volcanic eruptions along these narrow deep rifts

Convergent: Plates are colliding and one plate may be forced under the edge of the other (**subduction**). The rocks in both plates are subjected to tremendous stresses that cause:

- Shallow to deep-focus earthquakes
- Volcanic activity on the overriding plate as the crust below melts, e.g. strato-volcanoes
- Mountain belts as the pressure of the plates colliding forces the crust upwards

Transform: Plates are moving side by side in opposite directions. Friction causes:

- Shallow-focus earthquakes
- Features are moved sideways and are offset

Materials

2 Thinsulite camping foamies, about 2 m long
2 pieces of thick foam (5-10 cm thick) each 50 cm x 80 cm
2 paper cones

Caution

For the mantle convection model, ensure that participating students act within their physical capabilities.

Modelling Tectonic Boundaries

Time

Medium

Grouping

Small groups, whole group

Preparation

Pre-test the equipment to determine the suitability of the foam sheets. Some may be too thin or too thick to demonstrate the desired motion.

Prompt

Show a map of the surface motion of the Earth (see Mapping Surface Motion activity). Ask students how the different sections of the Earth's surface are moving relative to one another.

Delivery

1. Provide students with 2 foamies that represent oceanic plates, and 2 pieces of thick foam that represent continental plates. Allow 10 minutes for students to simulate and explore the effects of the different ways that the plates can move relative to each other. Ask students where earthquakes will occur in their model? Where would they find volcanoes?
2. As a whole group, guide the students to discover:
    a. **Subduction**: Collide a foamie (oceanic plate) with a thick foam piece (continental plate) and slide it underneath the thick foam. The foamie will bend downward, showing subduction of the oceanic plate. In the middle of the thick foam piece, place 2 paper cones above the subducting oceanic plate to represent volcanoes that are caused by melting in the mantle. oceanic plate.
    b. **Mountain building**: Collide two thick foam pieces together and see how they buckle and push upward, like mountain building when two continental plates collide.
    c. **Transform boundaries**: Take any two pieces (foamies or thick foam) and slide them past each other, edge to edge.
    d. **Spreading ridge**: Put the two foamies together and push them up vertically between two desks or two students. Pull the leading edge of the foamies

upwards and away from each other. This models volcanic material being added at the ridge and the conveyor belt motion of the oceanic plate away from the ridge.

e. **Age of the oceanic crust**: Set up the first step of the spreading ridge model. Pull 20 cm of the foamies away from the ridge. Label the rocks being formed on both sides of the ridge “Monday.” Pull each of the foamies another 20 cm away from the ridge, and label the rocks at the ridge “Tuesday.” Repeat 3 times for the remaining days of the week. Ask students to describe where the oldest oceanic crust is to be found (Answer: away from the ridge), and what pattern they see in the age of the oceanic crust (Answer: stripes of the same age on either side of the ridge).

f. **Mantle convection**: Have two students crouch on their knees, back-to-back, ready to do a somersault in opposite directions. Drape two thin foamies between their backs and over their heads. Have the students do a somersault and observe how the foamies move in opposite directions, away from each other. This shows the relative motion of convection circulation in the mantle (the somersaulting students) and the oceanic plates (the foamies) moving away from each other at spreading ridges.

Questions for Discussion

Are there any gaps between the tectonic plates? (Answer: no)

Where do we find these different boundary types around the world?

Extensions

Add arrows to show magnetic reversal on the oceanic crust being formed at a spreading ridge. Observe the patterns produced.

Draw sketches of each type of boundary

Investigate the tectonic setting of a particular area, e.g. the Pacific Coast, and recreate the plate motions using the model.

Place two phone books together with the spines facing outward. Push the books into each other to demonstrate and investigate two continental plates colliding. Observe the structures created, including folds, up-thrust faults and inter-splintered rock layers.

Shoebox Spreading Ridge

Students model oceanic crust being created at a spreading ridge.

Explanation

The shoebox model (see Example) represents two tectonic plates at a divergent plate boundary. At a rift boundary, as the plates pull apart, magma from the mantle wells up into the lithosphere at the “crack” between the plates. Convection currents within the magma carry the floating plates away from the rift zone and as the magma hardens, it forms new oceanic crust. The stripes actually represent periodic shifts in the magnetic poles over geological time and, when recognized as such and mapped, they provided one of the best pieces of evidence for the plate tectonic theory.

Materials

World map
Shoebox
Scissors or craft knife
Two partial rolls of paper towels (about 10 sheets each)
Markers
Student Activity Page

Caution

Students must use scissors and/or craft knife carefully.

Time

Medium

Grouping

Pairs, small groups

Preparation

Reproduce Student Activity Page

Optional: Cut slits into the shoebox lids for the student models.

Prompt

None

Delivery

Distribute Student Activity Page and allow students time to build their models and simulate the movement of oceanic plates at a spreading ridge

Questions for Discussion

What do the slits in the shoebox lid represent?

Where are the oldest rocks?

Where are the youngest rocks?

Describe the pattern of magnetic stripes around the ridge.

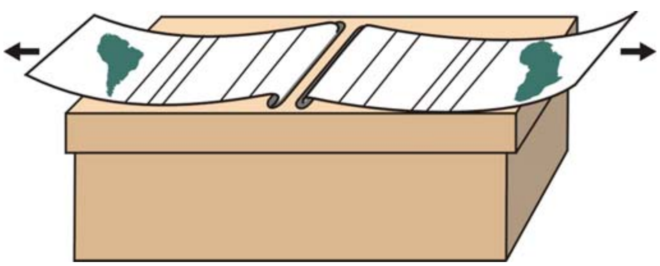
How does this model help explain why the oldest ocean rock is only about 200 million years old, when the age of the Earth is about 4.6 billion years?

Extension

Look at a bathymetric map of the oceans and identify features related to tectonics.

Resources

Example of Assembled Shoebox



You are going to build a model of oceanic crust being created at a spreading ridge.

Materials

World map
Shoebox
Scissors or craft knife
Two partial rolls of paper towels
Markers

Instructions

1. Draw a picture of South America on the first sheet of one paper towel roll, and a picture of Africa on the first sheet of the other roll.
2. Draw a pattern of lines across the other sheets in different colours and spacing so that the two rolls have the exact same striped pattern. These lines represent the magnetic stripes that help tell the age of the rocks on the ocean floor.
3. Roll the paper towels back up, and place them into the shoebox
4. Cut two parallel slits in the shoebox lid, about 2 cm apart, each slightly wider than the paper towels.
5. Put the lid back onto the box and feed the first sheets of the paper towels out of the slit in the box lid so that the edges meet.
6. Slowly start pulling the paper towels outward. Africa and South America should be side by side.
7. Keep pulling and see how the land separates and then moves apart. New ocean floor is created. The magnetic strips will be symmetrical on either side of the rift zone.

Subducting Earthquakes

Students create a model of earthquake foci along a subduction zone.

Explanation

The west coast of South America is located along a convergent plate boundary. The Nazca Plate, to the west under the Pacific Ocean, is moving eastwards and subducting under the South American Plate. There are two sources of earthquakes in a subduction zone: those caused at shallow depths near the surface, due to the collision of the two plates, and those caused along the interface between the two plates. This interface follows the Nazca Plate as it submerges below Chile. At about 600 km depth, the earthquakes stop. The reason for this is assumed to be because the plates are no longer rigid (**brittle**) enough to produce earthquakes; the temperature and pressures are so high that the rocks are now malleable (**ductile**).

The **epicentre** of an earthquake is the point on the Earth's surface immediately above the earthquake source. The actual point where the earthquake occurs is called the **focus** or **hypocentre**.

Materials

Pompoms
Measuring tape
Masking tape
String
Student Activity Page

Caution

None

Time

Medium

Grouping

Pairs, small groups

Preparation

Reproduce Student Activity Page and assemble materials.

Prompt

Show a map of earthquake distribution around the world. Remind students that this is an important piece of evidence that helps us understand the Earth's structure. Tell them that while the effects of earthquakes are felt at the surface, the source of the earthquake can be located at various depths under the surface of the Earth We can learn much about the Earth's structure by looking at the actual location where earthquakes occur.

Delivery

Distribute materials and allow time for students to create their models. They may need assistance in calculating a scale and in understanding the use of negative numbers to indicate that the earthquake happened under the ocean floor.

Question for Discussion

What could be happening to create this pattern of earthquakes under the coast of Chile?

Extension

Create a three-dimensional model by hanging pompoms from a box lid and using data from a whole region. The west coast of Canada is a suitable area to map.

The data below is from 25 earthquakes that occurred between 2004 and 2006 in Chile. They have been chosen along a line running east-west through the country. Your task is to create a model showing the location of each earthquake.

Materials

Pompoms
Measuring tape
Masking tape
String

Instructions

1. Calculate a scale that will allow you to display all the distances and depths in the space available, e.g. across the room, along the edge of a table. The negative numbers in the first column (distance from coast) mean that the earthquake happened under the ocean floor off the coast of Chile. The positive numbers indicate that the earthquake occurred below the country.
2. Cut lengths of string corresponding to the depths of the earthquakes. Tie pompoms to the ends of the string.
3. Hang the strings at the correct positions to show where the earthquakes occurred.

Data

Distance from coast (km)	Depth (km)	Magnitude
-171	10	4
-111	20	4
-62	17	4
-47	37	4.1
-20	28	4.2
-7	12	4.3
4	27	4.3
55	56	4.5
90	45	4.5
102	82	4.5
179	7	4.6
189	82	4.7
236	86	4.8
296	92	4.9
344	105	4.9
392	138	4.9
418	133	5
457	172	5
484	155	5.1
567	22	6
641	65	6.2
839	526	6.4
844	569	6.7
895	608	6.7

Sand Folds and Faults

Students will create a model using layers of sand and flour to simulate folding and faulting as seen in rock layers.

Explanation

When a force acts on materials, they can either bend or break. Bending is **ductile** behaviour and breaking is **brittle** behaviour. Where the Earth's rocks are ductile, they will slowly bend and fold under the tectonic stresses across the region, without causing earthquakes. However, where conditions make the rocks brittle, then faulting and earthquakes can occur.

Materials

Transparent plastic box (e.g. Ferrero-Rocher chocolate box)
Thick cardboard to tightly fit in plastic box as a vertical partition
Dry sand
Flour

Caution

This activity can create dust. Be aware of respiratory sensitivities.

Time

Short

Grouping

Whole group, small groups

Preparation

Build the model:

1. Place the cardboard in the transparent box so that it fits snugly against one end of the box.
2. Pour in a layer of sand approximately one cm thick. Sprinkle a thin layer of flour on top of the sand. Continue to alternate layers of sand and flour until the box is about half full.

Sand Folds and Faults

Prompt

Show photographs of mountains and ask students how they think the mountains have been made.

Delivery

This may be delivered as a student activity or teacher demonstration. It may also be done on a larger scale in an aquarium.

1. Grip the piece of cardboard and move it slowly and gently toward the opposite end of the box
2. Stop when it is about halfway there
3. Look at how the layers have moved. Some have bent (folds) while others have slid up or down (faults)

Questions for Discussion

How does the model represent what happens when tectonic plates collide?

What are the weaknesses with the model in representing tectonic processes?

Extension

Model folds and faults using layers of playdough to investigate the surface patterns produced.

Topography of Plate Boundaries

Students construct a topographic cross-section over the Gorda Ridge, Juan de Fuca Plate and Cascadia Subduction Zone.

Explanation

The west coast of Vancouver Island is a convergent plate boundary where the thin (7 km thick) Juan de Fuca Plate and the thick (20-40 km thick) continental plate of North America are colliding. These two plates approach each other with a velocity between 4 and 7 cm per year, about the rate your fingernails grow. The thinner, more pliable and denser Juan de Fuca Plate is being over-ridden and subducted beneath the leading edge of the North American Plate at the Cascadia Subduction Zone.

Further west in the Pacific Ocean is a divergent plate boundary at the Gorda Ridge, where new ocean floor is created as plates spread apart and move away from the ridge.

Materials

Juan de Fuca Plate relief map (see Resources)
Graph paper
Ruler
Pencils
Student Activity Page

Caution

None

Time

Medium

Grouping

Individual, pairs

Preparation

Reproduce student pages and the Juan de Fuca Plate relief map for each group.

Prompt

Use two foam sheets and have students assist you in demonstrating how two plates may either collide or move apart. Notice that the surface of the foam sheets changes shape as they converge or diverge. This is what is seen with tectonic plates and Earth scientists can identify plate boundaries by looking at the topography of a region.

Delivery

Distribute materials and allow students time to construct their cross-section. You may need to provide assistance in calculating a scale for the vertical axis.

Questions for Discussion

Where are the plate boundaries?

What processes are happening at the boundaries?

What hazards do these boundaries present to the region?

Extensions

Locate the most recent earthquakes on Canada's west coast using the Earthquakes Canada website: http://earthquakescanada.nrcan.gc.ca/recent/index-eng.php.

Discuss how they fit into the tectonic situation for that region.

You are going to look at the tectonic situation found on Canada's west coast. Use the detailed portion of the Juan de Fuca Plate relief map provided below to construct a topographic cross-section from east-west across the plate.

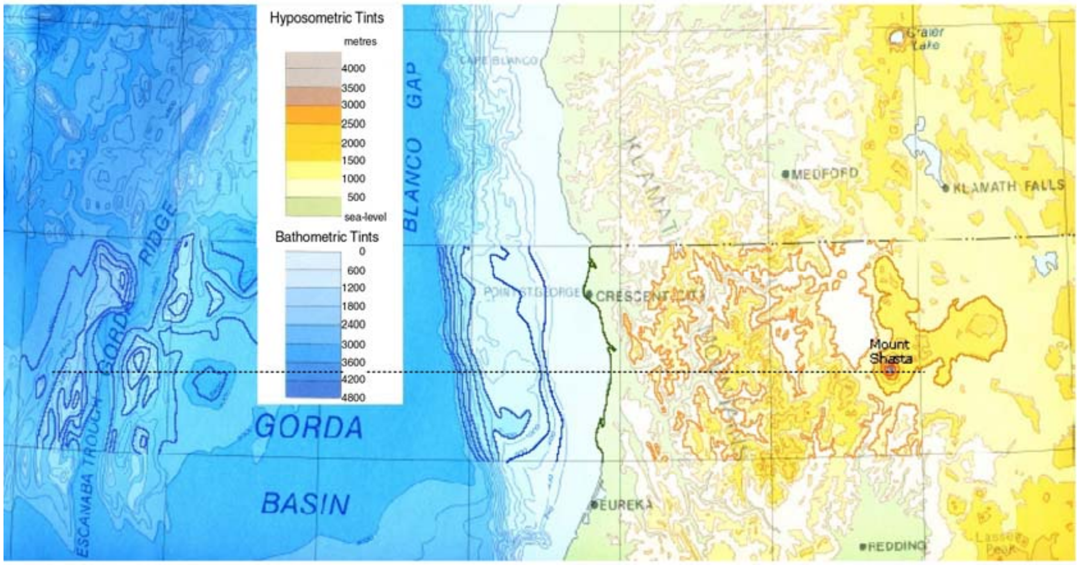
Materials

Juan de Fuca Plate relief map
Graph paper
Ruler
Pencils

Instructions

1. Place the graph paper along the line of the cross-section marked on the map.
2. Mark off each contour on the edge of the graph paper, and record the height or depth by each mark.
3. Across the middle of the graph paper, draw a horizontal axis the same length as the cross-section.
4. Add a vertical axis at each end of the line and scale it to fit the maximum heights you have recorded. The vertical axis will extend above and below the horizontal axis.
5. Transfer the contour heights to points on the graph join up the points.
6. Label the features:
   a. Diverging and converging plate boundaries
   b. Rift at the centre of a spreading ridge
   c. Continental slope
   d. Continental shelf
   e. Mountains and volcanoes
7. Mark where you would expect to see earthquakes occurring.

Worksheet: Cross-Section using Juan de Fuca Plate relief map



First Nations Knowledge of Earthquakes

Students hear how written and oral histories can be seen as first-hand experiences of natural events, in this case the last great megathrust earthquake off the Pacific Coast of North America that occurred January 26, 1700.

Explanation

The last great megathrust earthquake on the Pacific Coast of North America was on January 26, 1700 at 9 p.m. We know the time and date with such precision because the earthquake caused a tsunami that was recorded in the daily logs of harbour masters along the east coast of Japan. Modern-day researchers were able to take those wave arrival times and calculate where and when a magnitude 8 or greater earthquake had to have occurred to create that tsunami. They determined that the source had to be off Vancouver Island, where the subducting oceanic Juan de Fuca Plate lurched under the continental North American Plate. They were also able to estimate that the tsunami would have been about 10 metres high on the open western coasts of Vancouver Island and much higher in some inlets. The 1700 date has been confirmed by tree-ring dating of trees on the Washington coast.

The earthquake took place before colonial settlement of the west coast, and so there are no written accounts of it, but earthquakes are part of the oral history of the First Nations people of the west coast. Indeed, these First Nation communities along the coast would have experienced several earthquakes (or "ground shaking" as they described such events) through the ages, with some earthquakes originating in the oceanic crust of the subducting plate, and others along faults in the over-riding continental plate. In addition to earthquakes, they likely experienced tsunamis from distant sources that arrived without any local shaking. Only megathrust earthquakes would cause both strong shaking and tsunami.

Of all the earthquake-related information from First Nations oral histories, some of the most compelling comes from carvings on an 19th century interior screen in a Nuu-Chah-Nulth house. The screen is now on display at the Canadian Museum of Civilization in Gatineau, Quebec, and it is described as follows:

"The screen portrays two prominent Thunderbirds. Down each side of the screen are the tails of Killer Whales breaching the surface of the ocean. The creatures with large heads, protruding tongues and curled tails are likely supernatural Sea

Serpents, Thunderbird's spirit helpers. The circle in the middle, with an oval centre, may signify a phase of the moon as well as a portal. The circles containing a cross probably symbolize the earth and the four sacred cardinal points of the compass."

According to the US Naval Observatory Applications Department, on the evening of January 26, 1700, sunset along the Washington coast was at 5:10 PM Pacific Standard Time, and the Moon rose at 5:21 PM. The Moon was a waxing crescent with 36% of the Moon's disk illuminated. The Moon would have had pronounced "horns" pointing upward and to the left – precisely what is depicted in the Nuu-Chah-Nulth screen. This convergence of written and oral history demonstrates that much of the information contained in First Nations art and stories is a faithful record of their observations and experiences.

Materials

Basin
Brick
Marble
Story "Thunderbird and Whale" (see Resources)

Caution

Clean up spills immediately.

Time

Medium

Grouping

Whole group

Preparation

Fill a sink or basin with water sufficient to come up almost to the level of the brick that you are going to use for the demonstration.

Prompt

1. Explain to students that the water represents the Pacific Ocean.
2. Put a brick along the top left-hand corner of the basin to simulate Japan.

3. Drop a marble in the sink at the bottom right-hand corner and watch the "tsunami" propagate across the ocean to hit the eastward facing shore of "Japan."
4. Change the position of where you drop the marble and see how the wave pattern changes. Explain that in an earthquake, all we record are either the tsunami or seismic waves. Seismologists can calculate the source location by looking at the pattern of waves.

Delivery

1. After completing the demonstration, ask students how we know earthquakes happened before we had the technology to record the tsunami or seismic waves? Introduce the idea of oral tales and written stories as evidence for actual events. Mention age-appropriate books of real events, e.g. The Diary of Anne Frank, Sadako and the Thousand Paper Cranes.
2. Read aloud the tale of "Thunderbird and Whale," which is a composite of several stories from the Quileute/Hoh people on the west coast of the Olympic Peninsula.
3. After the story, ask students to identify what parts of the story might refer to an earthquake or tsunami.
4. Share the following quotes from west coast First Nations oral history that are thought to be connected to a giant earthquake and tsunami:
   a. Pachena Bay: "...It was night time that the land shook... a big wave smashed the beach...The Pachena Bay people were lost."
   b. Cowichan: "It began about the middle of one night...It was so severe… it threw down their houses and brought great masses of rock down from the mountains. One village was completely buried..."
   c. Makah: "The water flowed from Neah Bay, through the Waatch Prairie, and Cape Flattery was an island."
   d. Clallam: "The rivers became salt...the valleys were full of water."
5. Tell students that by putting these First Nation oral histories together with recorded information from 1700 about a tsunami in Japan, along with tree-ring dating and how we locate earthquakes by recording tsunami and seismic waves, researchers have proved that on January 26, 1700 at 9 p.m. there was a magnitude 8 or greater earthquake just off Vancouver Island. Select additional information as appropriate from the explanation section above.

Questions for Discussion

How would the First Nations stories change with retelling over 300 years?

How would the same earthquake, experienced by forest dwellers be described differently from the stories of coastal dwellers?

Extensions

Ask students to write their own legend about what causes earthquakes.

Have the students illustrate the Thunderbird and Whale story.

Make up math problems related to the velocity of the wave: If the wave travels at a speed of 500 km/second, how long will it take to cross the 3000 km Pacific Ocean?

Investigate the emergency preparations in place for another giant megathrust earthquake and tsunami on the west coast.

Resources

Thunderbird and Whale

Thunderbird soared far out over the placid waters and waited for Whale to come to the surface. As quick as a flash, the powerful bird darted and seized Whale in her flinty talons, lifted it and soared away toward the land.

Passing beyond the oceans Thunderbird was compelled to alight and rest her wings, and each and every time the bulky beast was allowed to reach solid land there was a terrible battle, for Whale was powerful and fought for its life with terrible energy. High into the air the Thunderbird carried Whale over the land, dropping it to the surface.

The great Thunderbird finally carried the weighty animal to her nest in the lofty mountains, and there the final and terrible contest was fought. There was a shaking up and trembling of the Earth beneath, and a rolling up of the great waters.

The waters receded and again rose. The water of the Pacific flowed through what is now swamp and prairie, westward from Neah Bay on the Strait of Juan de Fuca to the Pacific, making an island of Cape Flattery. Again the waters suddenly receded, and numerous sea monsters and whales were left on dry land. Each time the waters rose, the people took to their canoes and floated off as the winds and currents wafted them. Many canoes came down in trees and were destroyed, and numerous lives were lost.

Bending and Breaking

Students experiment with bending and breaking in brittle and ductile materials, and compare this to the behaviour of rocks in forming mountains and causing earthquakes.

Explanation

When a force acts on materials, they can either bend or break. Bending is **ductile** behaviour and breaking is **brittle** behaviour. Where the Earth's layers are ductile, they will slowly bend and fold under the tectonic stress across the region, without causing earthquakes. However, where conditions make the rocks brittle, then faulting and earthquakes can occur.

Earthquakes are produced in places where the tectonic plates are weaker, and less able to withstand the regional stress. Therefore, earthquakes are much more likely to occur on a pre-existing fault. **Seismologists** have a better idea of which areas are at risk by mapping fault lines, even ones that have not recently produced an earthquake.

Materials

Playdough
Can
Plastic knife
Popsicle stick

Caution

Break the Popsicle stick away from your face and those of your students.

Time

Short

Grouping

Individual, pairs, teacher demonstration

Preparation

Homemade playdough works very well for this task. Large batches are economical and can be vividly coloured with food dye.

Bending and Breaking

Prompt

Show photographs or media stories of recent earthquakes. Ask students what they think happens to the rocks to cause an earthquake.

Delivery

This may be done as a teacher demonstration or a student activity.

1. Roll out a sheet of playdough about the size of your hand. Lay the can on its side.
2. Place the layer of playdough over the side of the can and push down on the edges of the clay. Describe how the clay changes.
3. What would happen if you tried this experiment with a thin piece of wood and pushed very hard? Teacher can demonstrate this with a Popsicle stick.
4. Roll your playdough flat again and use the plastic knife to make a cut in the top of the sheet.
5. Lay the cut playdough over the side of the can and push gently down on the edges of the playdough. Where does the playdough bend or break first?

Questions for Discussion

The playdough and wood are models for how rocks behave in nature. If rocks bend like the playdough, what features will be produced? (Answer: hills and mountains)

When rocks break like the Popsicle stick, what will be produced? (Answer: faults and an earthquake)

Once a fault has broken the rock, just like the cut in the playdough, where is the next earthquake most likely to happen? (Answer: on the same fault)

Extension

Look at a map of regional or global earthquakes. Predict which areas are most likely and least likely to have future earthquakes.

Making an Earthquake

EARTHQUAKES

Students investigate the effect of friction in causing stick-slip motion along a surface, and compare this to an earthquake being caused as a fault moves.

Explanation

The continuous motion of the Earth's tectonic plates causes stress to extend throughout the plates. Earthquakes occur anywhere the local strength of the rock is less than the level of tectonic stress across the region (**regional stress).** Once the frictional strength of the fault (or rock) is exceeded, the two sides move along the fault causing an earthquake.

Stress is continually present in the plates, and earthquakes act to relieve that stress. Assuming that the increase in stress at a fault due to plate motion is constant, and if there is a greater time between repeating earthquakes on that fault, then there is greater stress release when the earthquake occurs and a larger magnitude earthquake is the result.

In this activity, the pulling force on the string represents the regional stress. The elastic stretches, and the length of the elastic is proportional to the **shear stress** applied to the wood block, representing the stress on the fault. In theory, the block should move when the shear stress exceeds the static friction, and it should stop again when the shear stress is less than the kinetic friction.

Repeating the **stick-slip** sequence for the wooden block leads to conclusions on earthquake recurrence on a fault (**seismicity**). There may be cases in which the local friction under the block is greater than usual, requiring more shear stress to accumulate before the block moves. By measuring the time between movements, the shear stress (the length of the elastic) and the amount of motion of the block, it can be shown that small motions occur after short times and large motions occur after longer periods of **quiescence**. This is the same as patterns observed in nature, and these are referred to as either **slip predictable** or **time predictable** models of earthquake recurrence.

The probability of an earthquake occurring at any time on a fault is related to how long it has been since the last earthquake, how large that earthquake was, and the regional stress existing. Detailed observation of seismicity patterns is the most promising (yet still unreliable) method of predicting earthquakes.

Making an Earthquake

Materials

Wood block with eyelet attached
Elastic band
String
Board smooth on one side, sandpaper-covered on the other
Safety goggles

Caution

Wear safety goggles during the experiment.

Time

Short

Grouping

Individual, pairs, whole group demonstration

Preparation

The relative dimensions of the equipment are important for the experiment to succeed. Test your equipment before class. Ensure that:

- The elastic band stretches easily, and at about 50% extension can pull the block.
- There is enough friction between the wood block and the sandpaper-covered board so that it sticks when gently pulled. To increase the friction put sandpaper or a piece of carpet on the block, add a weight to the block, or use a brick.
- The board is long enough for the block to jerk forward 3 or 4 times as it sticks and slips.

Prompt

Show photographs or media stories of recent earthquakes. Ask students how often earthquakes occur on the same fault? Why do they think that sometimes the fault moves, and sometimes it doesn't?

Delivery

This may be done as a teacher demonstration or a student activity.

1. Lay the board on the floor or table so that it is flat and the sandpaper side is up.

2. Connect the elastic band to the eyelet on the block, and the string to the elastic band.
3. Put the block at one end of the board with the sandpaper side down.
4. Very gently pull on the string. Try to maintain a constant pull. Observe how the block moves.
5. Now turn the board and wood block over and put the smooth sides together. Very gently pull the block along the board with the string. How does the block move now?

Questions for Discussion

When did the block move more easily? When the sandpaper-covered or smooth sides were together?

Why does the block sometimes stick, and then slip and move again?

If the block represents how rocks move, which part of the movement causes an earthquake?

What happens in nature when there is very little friction on a fault?

Extensions

Use a spring balance instead of the elastic to record the changing force on the block, and add a horizontal scale to measure slip.

Connect a model building to the block or place a pan of water on the top of the block to show the effects of an earthquake.

The Human Wave

Students take part in a whole group model of how the two types of body waves (P and S waves) travel in solids and liquids.

Explanation

All earthquakes produce a variety of seismic waves, which are distinguished by the nature of the vibration or individual particle motion in the wave, and by the area through which they propagate. There are four main types:

Body waves travel through the whole Earth. There are two types:

- **Primary** or **P waves** are compression or longitudinal waves where each particle vibrates in the same direction as the wave travels. P waves can pass through solids and liquids. They are the fastest seismic wave and usually arrive first at a seismic station.
- **Secondary** or **S waves** are shear or transverse waves where each particle vibrates perpendicular to the direction the wave travels. S waves can only pass through solids.

Surface waves travel only along the surface of the Earth. They travel slower than body waves, but are usually larger. The effects of surface waves are often more severe and occur at greater distances from the epicentre than body waves. There are two types of surface waves:

- **Love waves** are shear waves, with each particle vibrating from side to side on the surface; perpendicular to the direction the wave travels.
- **Rayleigh waves** are the slowest seismic wave, with each particle moving in an ellipse parallel to the direction of the wave.

Materials

None

Caution

Choose an open space so that no one in the line is within arm’s reach of any hazards, e.g. tables, windows.

Have a “spotter" at the end of the line in case the last person begins to fall.

Time

Short

Grouping

Whole group

Preparation

Select a suitable space for this activity: a hallway or gym is ideal.

Prompt

Place a CD player in one corner of the room and play some music. Ask a student on the opposite side of the room if they can hear it. Ask students to explain how the music travels from the player to the person. Explain that just as sound waves travel through the air, earthquake waves (**seismic waves)** travel through rocks.

Delivery

Lead this as a whole group activity; those not in the line should be observing what happens.

Solid: Position about 10 volunteers in a line, all facing the same direction, shoulder to shoulder, with their feet placed shoulder-width apart. Tell them that they represent the particles in a solid. Instruct them to not be too rigid or too limp when pushed. They should give with the force that they will feel from the person next to them, but not fall over, and then return to their upright position. In other words, they should be "elastic."

1. Ask everyone in the line to link elbows, or put their arms over the shoulders of the person next to them “chorus line” style. Have the first person at one end of the line lean into the person next to them, pushing against their shoulder, and then straighten back up. This makes an “earthquake.”
    a. Questions: Which way is the wave travelling? In which direction did each of you move? Do the particles of the solid (you) end up in a different place?
    b. Discuss: This is a **P wave** because each particle moves in the same direction as the wave as a whole. It is called a compression or longitudinal wave. You may find it useful to remember P as “push-pull,” although this is not a technical term.

2. Next, have the first person make a different type of earthquake wave. Lean forward at the waist and stand back up. Because each person in the line is linked, they all do the same movement, and the wave passes along the line of people.
   a. Questions: How does this wave move? How do the particles move?
   b. Discuss: This is an **S wave** because each particle moves in a direction perpendicular to the wave as a whole. It is called a shear or transverse wave. You may find it easy to remember S as "sideways," although this is not a technical term.

Liquid: To model particles in a liquid, ask everyone to release their arms. They should still be standing so that their shoulders touch, with their arms at their sides. Repeat the process in steps 1 and 2 above to create a P wave and S wave, making the same observations.

Discuss: P waves move through a liquid as easily as through a solid. The wave does not need strong bonding between the particles to propagate. S waves cannot move through a liquid because the shear motion is not transferred between particles that are not strongly bonded together.

Conclusions: With arms linked, the line of students represents a solid and both types of waves pass down the line. Without arms linked, representing a liquid, only the compression waves (P waves) will be transferred from person to person. A shear wave (S wave) will not travel in a liquid. Explain to students that these properties of earthquake body waves are the most important way in which we study what's inside the Earth.

Hints: If the S wave doesn't pass easily along the "solid" line, suggest that the particles need to be more closely bonded, i.e. make sure participants are firmly linked and they are standing close to each other. If the S wave does pass along the "liquid" line, ask the second particle if they truly felt any pull from the first person. Often participants will lean forward simply because they did that in the first part, or they assume that something *should* happen.

Extension

Time the P and S wave propagation in the human wave using a stopwatch. Because the shear wave motion is more complicated in the human wave, the S wave will have a slower velocity (greater travel time from source to the end of the line of people), similar to seismic waves in a solid.

Earthquakes with Slinkies

Students investigate wave properties using Slinky toys, and relate their observations to earthquakes.

Explanation

All earthquakes produce a variety of seismic waves, which are distinguished by the nature of the vibration or individual particle motion in the wave, and by the area through which they propagate. There are four main types:

Body waves travel through the whole Earth. There are two types:

- **Primary** or **P waves** are compression or longitudinal waves where each particle vibrates in the same direction as the wave travels. P waves can pass through solids and liquids. They are the fastest seismic wave and usually arrive first at a seismic station.
- **Secondary** or **S waves** are shear or transverse waves where each particle vibrates perpendicular to the direction the wave travels. S waves can only pass through solids.

Surface waves travel only along the surface of the Earth. They travel slower than body waves, but are usually larger. The effects of surface waves are often more severe and occur at greater distances from the epicentre than body waves. There are two types of surface waves:

- **Love waves** are shear waves, with each particle vibrating from side to side on the surface; perpendicular to the direction the wave travels.
- **Rayleigh waves** are the slowest seismic wave, with each particle moving in an ellipse parallel to the direction of the wave.

Materials

Slinkies
Cardboard
Masking tape
Nylon stocking

Caution

Be careful not to overextend the Slinky.

Time

Short

Earthquakes with Slinkies

Grouping

Pairs, small groups, whole group

Prompt

Place a CD player in one corner of the room and play some music. Ask a student on the opposite side of the room if they can hear it. Ask students to explain how the music travels from the player to the person. Explain that just as sound waves travel through the air, earthquake waves (**seismic waves**) travel through rocks.

Delivery

Arrange two students sitting opposite each other across a table, with each holding one end of a Slinky.

1. Basic Waves
   a. Ask students to extend their Slinky to about 1 ½ times its unstretched length.
   b. Hold one end still. Gently push one end in and out, toward the other student. What happens to the coils of the Slinky? These are earthquake P waves or "Primary" waves; use "P for push and pull" as a reminder.
   c. Now gently move one end of the Slinky from side to side. What happens to the coils of the Slinky this time? These are earthquake S waves or "Secondary" waves; use "S for sideways" as a reminder.
2. Waves Transfer Energy
   a. Have students make a model building from card, and tape it to the middle of the Slinky.
   b. Investigate how the building moves when an S wave passes.
   c. How does the building move when a P wave passes?
   d. What makes the building move?
   e. Discuss: The wave carries energy from the earthquake source and transfers it to the building, making it shake.
3. Absorption
   a. Have students push a nylon stocking into the Slinky coils.
   b. Now try making P and S waves.

c. Question: How is this different then when there was nothing inside the Slinky?

d. Discuss: The size of seismic waves is reduced as they travel through the ground. Energy is absorbed and the waves get smaller.

4. Spherical Dispersion

a. Collect 4 or 5 Slinkies. One person holds one end of as many Slinkies as they can, while other volunteers stretch them in all directions from the centre person, who will make an earthquake using either P or S waves.

b. Question: Which directions do the waves travel in?

c. Discuss: Earthquakes send seismic waves in all directions from the source, producing spherical wave fronts.

Questions for Discussion

What happens to the Earth during an earthquake?

How is energy released during an earthquake?

Why does damage sometimes occur many kilometres from the fault that moved to create the earthquake?

Extension

View free interactive online software that models the propagation of waves through the Earth for selected earthquakes: http://www.geol.binghamton.edu/faculty/jones/

Fault Types

Students build models of the different fault types, observing how motion on each causes earthquakes.

Explanation

In a **normal** fault, the block above the fault moves down relative to the block below the fault. This fault motion is caused by tensional forces and results in extension.

In a **reverse** fault, the block above the fault moves up relative to the block below the fault. This fault motion is caused by compression forces and results in shortening. A reverse fault is called a **thrust** fault if the dip of the fault plane is small.

In a **strike-slip** fault, the movement of blocks along a fault is horizontal. If the block on the far side of the fault moves to the left, the fault is called left-lateral. If the block on the far side moves to the right, the fault is called right-lateral. The fault motion of a strike-slip fault is caused by shearing forces.

Materials

Long stick
Coloured markers
Triangular cosmetic sponges
Fault type diagram (see Resources)

Caution

Break the stick well away from people's faces.

Time

Medium

Grouping

Individual, pairs

Preparation

Prepare an overhead of the three different types of faults.

Prompt

Break a long stick to model an earthquake. Ask students to look carefully at the broken ends and describe the break. Repeat with another section of the stick and see if the break is the same shape. Explain there are different ways that rocks can break and move along a fault to create an earthquake.

Delivery

1. Give each group two cosmetic sponges, and have them place the sponges side by side to make a rectangular prism.
2. Colour a simple landscape on the top surface: a river, road, house, etc. The landscape will go across the join between the two sponges.
3. Have students experiment with moving the two sponges vertically and horizontally along the join (fault) and observe how the landscape patterns change. They could make sketches of their observations.
4. Display the overhead of the three fault types and have students recreate normal, reverse (thrust) and strike-slip faults using their models.

Questions for Discussion

Cut a loaf of bread lengthways into 4 slices. Sandwich it together with layers of jam, honey and Cheese Whiz. Make one slanted vertical cut through the middle of the loaf.

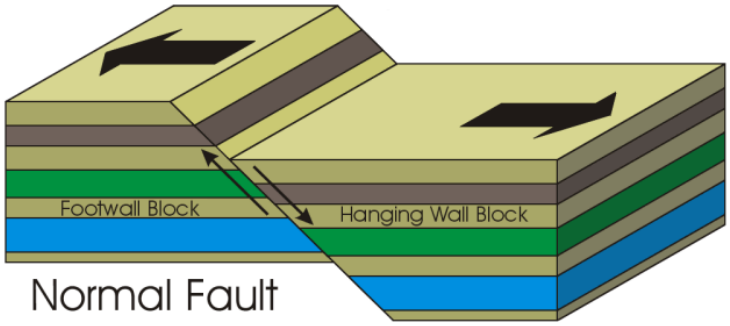
Use this model to produce the three fault types and have students name each one.

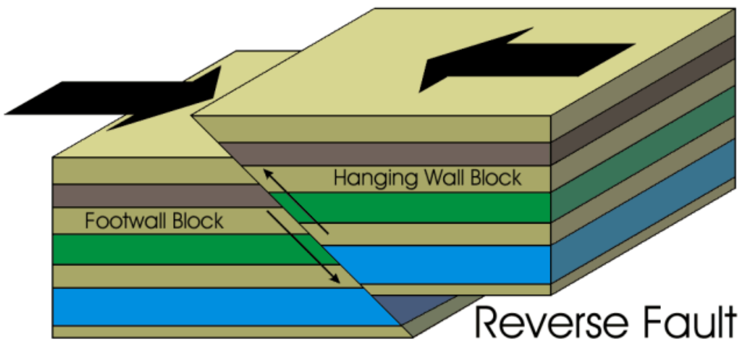
Extension

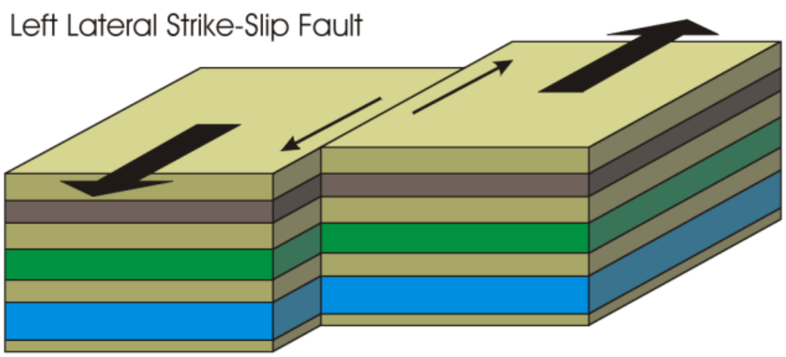
View online animations of fault movement and photographs of faults at http://www.iris.edu

Resources

Fault Types


Footwall Block
Hanging Wall Block
Normal Fault


Hanging Wall Block
Footwall Block
Reverse Fault


Left Lateral Strike-Slip Fault

Making a Tsunami

Using a model, students investigate how the movement of the ocean floor causes a tsunami, and how the tsunami changes as it nears land.

Explanation

For a tsunami to be generated by an earthquake you need:

- An earthquake of magnitude 8 or greater
- The fault, where the earthquake occurs, to be under the ocean
- Vertical movement on one side of the fault

Fortunately, it is unusual to have all three conditions met, and, as a result, damaging tsunamis are relatively rare. The main feature of a tsunami that makes them so damaging is that when the tsunami travels into shallower water, the wave height increases.

The magnitude of the earthquake that causes the tsunami is proportional to the length of the fault rupture or break. The Sumatra earthquake in December 2004 was magnitude 9.1 and occurred on a fault about 1200 km long. The event lifted up the sea floor several metres, generating the tsunami that caused so much devastation around the Indian Ocean.

Materials

Fault model (see Preparation)
Cardboard box 35 x 25 cm, about 11 cm deep
6 clothes pins
Thin plastic sheet
Craft knife
Stiff rectangular object 8 x 24 cm, e.g. plastic sheet, wood block
Plastic container about 1/3 the depth of the box, e.g. small margarine container
Water

Caution

Clean up any spills immediately.

Time

Short

Grouping

Small groups, whole group

Preparation

Build a fault model:

1. Cut a loaf of bread lengthways into 4 slices.
2. Sandwich it together with layers of jam, honey and Cheese Whiz.
3. Make one slanted vertical cut through the middle of the loaf.

Alternatively, use blocks of coloured clay, playdough or sponge.

Build a basin model:

1. Cut a rectangle out of the bottom of one end of the cardboard box, about ½ cm larger on all sides than the stiff rectangular object.
2. Line the box loosely with plastic.
3. Secure the plastic to the top edge of the box with clothes pins.
4. Slip the stiff rectangle so it fits into the hole in the box bottom and can push the plastic liner up and down. This represents the fault.

Prompt

Using the fault model, have students demonstrate the different ways the fault can move: normal, reverse and strike-slip faults.

Delivery

This activity could be delivered as a teacher demonstration or a small group investigation.

1. Put about 5 cm of water in the basin model.
2. Very gently move the cut-out end of the box off the side of the table so that the rectangular object (the fault) is free to move. Keep the fault supported.
3. At the count of 3 shout, “Earthquake!” and quickly drop the fault. Observe what happens to the water.
4. At the count of 3 shout, “Earthquake!” and quickly push the fault up into the box. Observe what happens to the water.
5. At the count of 3 shout, “Earthquake!” and quickly move the fault to the left or right. Observe what happens to the water.
6. Put the margarine container, which will represent a beach, into the opposite end of the box to the fault. Repeat steps

3, 4 and 5. Observe carefully the wave as it travels over the beach.

Questions for Discussion

Which type of fault motion produced the biggest wave?

How does having a beach affect the wave?

Extension

Investigate historical tsunamis, their frequency and human impact.

Soil Liquefaction from Earthquakes

Students observe how shaking can liquefy wet sand, and correlate this to the effects of earthquakes.

Explanation

The effects of an earthquake are often more severe in areas where the rock is sandy or with loose sediments as found in river valleys or deltas. In such areas, some of the spaces in sediments are filled with water, some with air. When an earthquake shakes the sediment, the water and air in the spaces are forced upwards. The surface sediments liquefy, making the ground lose its structural strength to the point where buildings can sink or collapse

Materials

See Delivery – alternate methods are included

Plastic tub
Sand
Water
Wooden blocks
Paper cup
Pie plate
Small washer
Cornstarch

Caution

Clean up any spills immediately.

Time

Short

Grouping

Pairs, small groups

Preparation

Assemble the equipment for each method chose

Delivery

You may choose any one or combinations of the following methods. They provide similar results.

Method 1:

1. Put the wooden blocks on the sand in the tub.
2. Add water to just dampen the sand.
3. Shake the plastic tubs side to side or tap them on the table to simulate an earthquake.
4. Observe what happens around and beneath the wooden blocks.

Method 2:

1. Place an upside-down cup with its bottom cut off into a pie plate, and fill the cup with sand.
2. Put a small washer or block on top of sand.
3. Pour water into pie plate, watching as it is absorbed into the sand.
4. Tap firmly on the edge of the pie plate and observe the washer.

Method 3:

Use oobleck (mixture of cornstarch and water) in place of sand for either method.

Question for Discussion

What might happen beneath buildings on sandy soil during an earthquake?

Extension

Investigate earthquake-resistant design and building code considerations for areas prone to liquefaction.

Shaking of Buildings During Earthquakes

Students investigate the natural resonance of short and tall objects, and correlate this to damage in buildings during earthquakes.

Explanation

Frequency is a measure of how many times a second something happens. For example, “5 hertz (Hz)” means “5 times a second.”

All buildings (indeed, all objects) have a **natural frequency**, which is the frequency of shaking at which the building is vibrated the largest distance. Taller buildings have a lower natural frequency; shorter buildings have a higher natural frequency. For example, a 2-floor house vibrates most at 5 Hz a 30-floor tower block will vibrate most at 0.3 Hz.

When an earthquake occurs, it produces seismic waves at a range of frequencies. Different types of buildings will suffer different damage because they vibrate more at some frequencies than others.

The frequency of the seismic waves during an earthquake changes at different places around the epicentre. Primarily, the frequency decreases as energy is absorbed by the ground (**attenuation**).

Materials

See Preparation section for suggestions.

Caution

None

Time

Short

Grouping

Individual, pairs or whole group

Preparation

Prepare some model buildings. Suggestions are:

- Cut two rectangles from thick craft foam, one 10 cm x 20 cm, the other 10 cm x 30 cm. Grip them between two paint-stirrers held with rubber bands.

- Cut two pieces of card, one 10 cm x 20 cm, the other 10 cm x 30 cm. Clip the card onto a ruler and weight the tops with paper clips.
- Build three-dimensional models from card or drinking straws.
- Use soft balls on wires of different lengths stuck into a Styrofoam block.

You will need at least 2 buildings: one short and one tall. Experiment with your design to ensure that the models vibrate visibly when you shake them. Make sure there is a clear difference between the response of the tall and short buildings. You should shake both models at the same time to remove the human variable in the experiment.

Prompt

Show photographs of earthquake damage in a city. Have students notice that some buildings are relatively unscathed, while others nearby are destroyed. Ask them to suggest reasons for these differences.

Ask students if they would feel safer during an earthquake in a tall building or a short one.

Delivery

1. Use a model of one short and one tall building. Create an earthquake by gently moving both buildings side to side, changing direction about once a second. Does one building shake more than the other? Which one?
2. Now create a second earthquake, this time move the buildings as quickly as you can side to side. Try to move the same distance as you did when you went slowly. Does one building shake more than the other? Which one?
3. Explain that all objects vibrate at a certain speed (use the term **frequency** if appropriate). Ask what happens when you make a guitar or violin string shorter? (Answer: The string vibrates faster and the note gets higher.) All long things vibrate slowly, short things vibrate quickly. It is the same for buildings. If the earthquake has lots of fast shaking, short buildings may be damaged more, while if it has lots of slow shaking, tall buildings may be more vulnerable.

Question for Discussion

How do we make sure this is a fair test of only the building height?

Extension

Investigate earthquake-resistant design of buildings.

Earthquakes in Canada

Students map the 10 largest Canadian earthquakes and create a graph showing how many earthquakes of each magnitude occurred in Canada in the past month.

Explanation

Small and moderate earthquakes happen frequently, but are typically not felt and cause no damage. Earthquakes are caused by tectonic stresses, without which the Earth would eventually be eroded into a flat sheet. Large earthquakes, those that are felt and cause damage, are less common and tend to occur in narrow bands around the Earth along the tectonic plate boundaries. The west coast of Canada is a very active tectonic region, with a subduction zone, a spreading ridge and a transform plate boundary.

Materials

Map of Canada
Pins or stickers
Online access or data for the past month's earthquakes (see Preparation)
Student Activity Page

Caution

Ensure students understand safe Internet use.

Time

Medium

Grouping

Individual, pairs

Preparation

Reproduce Student Activity Page.

Go to the Natural Resources Canada (NRCan) Earthquakes Canada website (http://earthquakescanada.nrcan.gc.ca) and access data for earthquakes that have occurred in the past month. In the online table format, you will find a list of every recorded event and a summary table of how many earthquakes in each magnitude range have occurred. The summary data is sufficient for this task.

Alternatively, bookmark the page for students to access the data for themselves.

Prompt

Ask students to predict how many earthquakes occurred in Canada during the past month. Ask if they think that Canada has ever had a magnitude 9 earthquake.

Delivery

Distribute Student Activity Page. Allow students time to complete the mapping and graphing exercises, and to answer the questions. You may need to assist with specific instructions on drawing a bar graph.

Review their maps and graphs as a whole group.

Questions for Discussion

With all the earthquakes that happened in the past month, why don't we hear about them all?

How long ago was the largest earthquake in Canada?

What do you think is the chance of a magnitude 9 earthquake happening again in the same place?

How do you think people in Canada should prepare for earthquakes?

Extension

Look at the global distribution of large earthquakes and identify regions of high and low risk.

Earthquakes in Canada

You will investigate the largest earthquakes recorded in Canada, and how many earthquakes happen in Canada each month.

Materials

Map of Canada
Pins or stickers
Graph paper
Ruler

Instructions

1. On the map of Canada, mark the location of the 10 largest Canadian earthquakes, as listed in the data table.
2. Complete the blank data table for how many earthquakes occurred in Canada in the past month.
3. Create a bar graph showing how many earthquakes of each magnitude occurred in Canada in the past month.

Questions

1. Which region of Canada has had the greatest number of large earthquakes in the past month?
2. What is the largest earthquake magnitude recorded in Canada?
3. How many earthquakes in total were there in the past month?
4. Which magnitude of earthquake happened more often in the past month?

Data: 10 Largest Canadian Earthquakes

Source: NRCan

Date	Latitude	Longitude	Magnitude	Location
1700/01/26	48.5	125	9.0	Cascadia subduction zone, British Columbia.
1949/08/22	53.62	133.27	8.1	Offshore Queen Charlotte Islands, British Columbia.
1970/06/24	51.77	130.76	7.4	South of Queen Charlotte Islands, British Columbia.
1933/11/20	73.00	70.75	7.3	Baffin Bay, Northwest Territories.
1946/06/23	49.76	125.34	7.3	Vancouver Island, British Columbia.
1929/11/18	44.50	56.30	7.2	Grand Banks south of Newfoundland.
1929/05/26	51.51	130.74	7.0	South of Queen Charlotte Islands, British Columbia.
1663/02/05	47.6	70.1	7.0	Charlevoix, Quebec.
1985/12/23	62.19	124.24	6.9	Nahanni region, Northwest Territories.
1918/12/06	49.62	125.92	6.9	Vancouver Island, British Columbia.

Earthquakes in Canada in the Previous Month

Magnitude	1	2	3	4	5	6	7
Number							

Magnitude and Intensity

Students participate in a demonstration of the magnitude of an earthquake and the intensity effects at different places, using an analogy to a heater.

Explanation

The size or **magnitude** of an earthquake is determined by how much energy is released at its source, the **earthquake focus**. Each earthquake has one magnitude.

The **intensity** of an earthquake is how much shaking is felt or measured at different places affected by the earthquake. Close to the earthquake, the intensity will be high; while farther away it will be lower. It is important to note that this is a much generalized statement intended to instil an initial understanding. In reality, there are many factors that influence earthquake intensity at a point, not only distance.

Materials

Heat source (e.g. radiant light bulb or tea light)
Optional: chocolates

Caution

Keep the heat source away from any flammable objects.

Time

Short

Grouping

Whole group demonstration

Preparation

None

Prompt

Display data of recent earthquakes, highlighting the numbers that describe magnitude and intensity. Explain to students that we are looking at what these numbers mean.

Delivery

1. Place a small heat source in the centre of the room so that students are distributed all around it. Lead observation and discussion about how the heat is distributed around the room. Ask students nearest to the heat: How warm does the heat feel? Ask those farther away: Can you feel the heat?
2. Optional demonstration with chocolate: If we placed a chocolate right next to the heat, would it melt? If we placed it at the edge of the room, would it melt?
3. Question: Is the power of the heat source changing?
4. Question: Why is the warmth different in different places around the room?
5. Conclusion: The heater, at its source, has only one level of power (magnitude) and this does not change. The heat and warmth (intensity) we feel at different places around the heater depend on how far we are from it, whether we are shaded from the heater, what clothes we are wearing, etc.
6. Make analogy to earthquakes where each earthquake has only one magnitude, but can create effects of different intensity at different places.

Extensions

Investigate the different magnitude and intensity scales.

Have students read seismograms and determine the magnitude for an earthquake in the Quake Chasers activity at www.Quakechasers.ca

Experiment with the IRIS Earthquake simulator at www.iris.edu,

Volcanoes and Viscosity

Students investigate the flow rates of liquids with different viscosity and silica content. They correlate their observations to oceanic and continental volcanoes.

Explanation

The second part of this experiment presents a good model of how silica content affects lava viscosity Lava with a high silica content is very viscous. This is the type of lava found in continental volcanoes (e.g. Mount St. Helens), and its flow pattern is what produces the steep-sided cones typical of this type of volcano. Lava with a low to no silica content is called basaltic lava, and is seen in volcanoes in the oceanic crust. Basaltic lava is very fluid and the volcanic cones created by it are wide with shallow, sloped sides (e.g. Hawaiian volcanoes).

Interpretation of the observations from this experiment must be handled carefully. Oceanic lava has different chemistry and properties to continental lava, but continental lava is the melted oceanic crust rising to the surface after the oceanic plate is subducted. As the molten oceanic crust rises, it reacts with the lithosphere and changes its chemistry. This is another cyclical process in geology. The two lava types have similar origins but differing characteristics.

Materials

Root beer and corn syrup
Cups
Drinking straws
3 liquids (see Preparation note)
Sand
Stopwatch
Plastic sheet marked with square cm grid
15 ml spoon
5 ml spoon
Mixing container
Student Activity Page

Caution

Clean up any spills immediately.

Students must not consume the liquids.

Use a new straw for each student in the opening activity.

Time

Long

Grouping

Pairs, small groups

Preparation

Assemble materials and cover the demonstration tables with plastic cloth to protect the surface. Select and pre-test the 3 liquids that the students will use for their experiment. It is important that these liquids have different physical properties, especially different viscosity. For example: dish detergent, vegetable oil, and liquid soap.

Prompt

1. Fill a cup about ¾ to the top with root beer, another cup ¾ full of corn syrup.
2. Place the cups on the plastic cloth.
3. Ask one student to lightly blow into the root beer with a straw, just until bubbles are produced. Observe what happens.
4. Have the same student use the same amount of force to blow into the corn syrup. Observe what happens. Blow harder until the corn syrup 'erupts.'

Ask students to describe how the eruptions of root beer and corn syrup differed from each other.

Explain they are going to investigate more about liquids and volcanic eruptions. Distribute Student Activity Pages.

Delivery

1. Read through the method with students.
    a. Discuss the scientific method of experimentation and performing a fair test. Ask students to identify the variables other than the liquid itself that will affect the results. Prompt them to consider how the liquid is poured onto the plastic sheet. Ask them how they will do it in their procedure: touch the spoon down, leave it still, take it away, pour from a height, etc? There is no one best way, but it must be done the same way in each test.
    b. Ask why it is necessary to rinse the sheet between steps. (Answer: to remove traces of the liquids) Is the

water an issue? (Answer: no, if the plastic is wet each time).

c. Revisit the method of measuring the area of an irregular shape by counting squares.

d. Instruct or remind students how to calculate the average of a group of numbers: average = sum of all the numbers/how many numbers

2. Give students time to complete their experiments.

3. Discuss the results as a whole group.

Questions for Discussion

Which liquid was the slowest?

Which liquid covered the largest area?

How would you describe the differences between the liquids as they flowed?

Lava can be thick or runny. What difference would that make to the shape of the volcanoes produced by the each type of lava flow?

Extension

Look at photographs of different types of volcanoes and identify if they were produced by viscous or fluid lava.

You will investigate how viscosity affects the shape of volcanoes.

Materials

3 liquids
Sand
Stopwatch
Plastic sheet marked with square cm grid
15 ml spoon
5 ml spoon
Mixing container

Instructions

Part 1

Test each liquid in turn, following the instructions below and recording your observations on the chart below.

1. Use the same volume of liquid for each test, for example 15 ml.
2. Put the liquid onto the centre of the plastic sheet in exactly the same way for each test.
3. Use the stopwatch to time how long it takes the liquid to stop spreading across the plastic.
4. Estimate the area covered by the liquid.
5. After each test, carefully pour the liquid back into its container.
6. Rinse the plastic sheet with water before doing another test.
7. Repeat each test at least 3 times.
8. Calculate the average time and area covered for each liquid.

Part 2

1. Choose one liquid only.
2. In the mixing container, stir together 15 ml of liquid and 5 ml of sand.
3. Test this mixture following the instructions above.
4. Observe the shape of the lava flow. Be sure to look at it from the side.
5. Add another 5 ml of sand to the mixture and repeat the test.
6. Add a third 5 ml of sand to the mixture and repeat the test.
7. When finished, rinse this mixture down the sink with cold running water.

Recording Charts

Part 1

Liquid	Test number	Time (seconds)	Average time (seconds)	Area (cm^2)	Average Area (cm^2)
	1				
	2				
	3				
	1				
	2				
	3				
	1				
	2				
	3				

Part 2

Sand	Time (seconds)	Area (cm^2)
5 ml		
10 ml		
15 ml		

A Wax Volcano

Students observe a demonstration that simulates rocks being formed by magma intrusions and volcanic eruptions.

Explanation

The layer of the Earth beneath the crust is called the **mantle**. Observations of seismic waves passing through the mantle show that it is mostly solid. Within the mantle are pockets of molten rock, which is called **magma**, and these are the source for volcanic eruptions at the surface. The magma erupts as lava and forms extrusive igneous rocks. The magma can also cool under the Earth's surface to form intrusive igneous rocks.

Materials

500 ml glass beaker
Red candle wax
Washed sand
Very cold water
Bunsen burner
Heatproof mat
Tripod
Gauze
Safety screen

Caution

Use a safety screen between the students and the beaker, or have them watch from at least 2 metres.

Presenter should wear safety goggles.

Time

Short

Grouping

Whole group demonstration

Preparation

Assemble the wax volcano:

1. Melt the red wax and pour a layer about 1 cm deep into the base of the beaker.
2. Spread a layer of sand about 1 cm deep above the wax.
3. Add very cold water to fill the beaker about ¾ full.

As the demonstration happens very quickly, it may be beneficial to have more than one model volcano available, so the "eruption" can be repeated.

Prompt

Show video clips or photographs of volcanic eruptions. Discuss what students think is underneath the volcano, and where new rocks are forming.

Delivery

1. Show students the model volcano. Explain:
    a. The sand and the water represent the crust of the Earth.
    b. The wax layer represents the solid mantle below the crust.
    c. The mantle will be heated at a point source.
2. Seat students behind the safety screen and tell them to watch carefully as the eruption will happen with little warning.
3. Place the beaker on the tripod and gauze.
4. Apply a strong Bunsen flame to the base of the beaker.
5. Wait for the "eruption."
6. Remove the Bunsen flame while there is still some wax left on the bottom of the beaker.
7. Discuss with the students what they observed:
    a. The molten wax rises, because of its lower density. It represents magma (molten rock).
    b. Some of the wax rises rapidly and erupts onto the surface. It is very runny and spreads out evenly over the surface of the water. Some lavas cover huge areas, arising from fissure eruptions.
    c. Some of the wax can be seen rising through "tubes" of wax, which insulate it from the surrounding cold water and enable it to reach the surface.
    d. Some of the wax sets very quickly in the cold water, forming grotesque shapes. These represent intrusive igneous rocks.
    e. Once the wax has all set, the "lava layer" may be removed and the water poured off, in order to study the shapes of the "intrusions." This is equivalent to the removal of layers of rocks by weathering and erosion.

Question for Discussion

How is the model not like the real world? (Answer: the most important difference is that the surface eruption sets very slowly, while the “intrusions” set very quickly. In nature, the reverse would be true, because of the higher temperatures at depth. Lavas may become solid within days, months or years, whereas a large, deep intrusion of magma may take millions of years to cool to the ambient temperature.)

Extensions

Demonstrate partial melting of rocks, where minerals with the lowest melting points are the ones that rise to the surface, by heating a mixture of chopped wax and gravel in a container. The wax melts and rises, while the gravel does not.

Research the three different types of magma and how they are formed.

Resources

Example of Assembled Wax Volcano Model