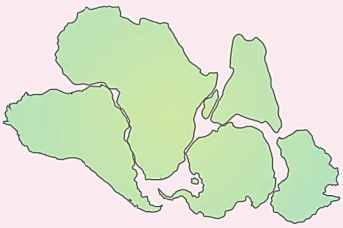
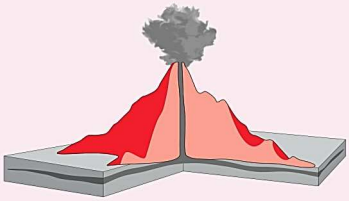
WASP
Woodside Australian Science Project
An initiative supported by Woodside and ESWA

Plate Tectonics Package

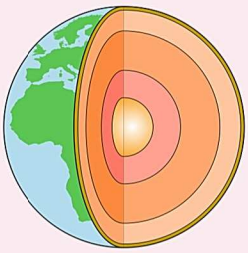
Continental Drift and Plate Tectonic Theory



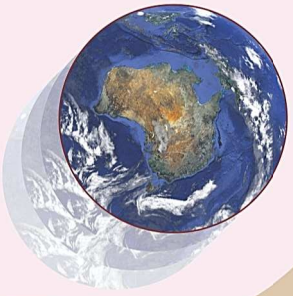
Relating Earthquakes and Volcanic Activity to Plate Boundaries



Great Iron Catastrophe (GIC) and Planetary Differentiation



Can Humans Move the Earth?



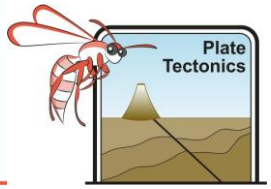
Year 9

Australian Curriculum - Earth and Physical Sciences

EARTH SCIENCE WESTERN AUSTRALIA

woodside

Year 9 WASP – Teacher Introduction



The WASP (Woodside Australian Science Project) is an initiative supported by Woodside and Earth Science Western Australia (ESWA).
These activities are designed to provide support for the Earth Science part of the Earth & Space Sciences and part of the Physical Sciences topic required by the Year 9 Australian Curriculum.

Copies of this and other supporting materials can be obtained from the WASP website http://www.wasp.edu.au or by contacting Julia Ferguson, julia@wasp.edu.au

Topic 1 **Continental Drift and Plate Tectonic Theory**
Topic 2 **Relating Earthquakes and Volcanic Activity to Plate Boundaries**
Topic 3 **Great Iron Catastrophe (GIC) and Planetary Differentiation**
Topic 4 **Can Humans Move the Earth?**

Year 9 Australian Curriculum Science

Earth & Space Science
The theory of Plate Tectonics explains global patterns of geological activity and continental movement (ACSSU180)

- Recognising major plates on a world map
- Modeling seafloor spreading
- Relating the occurrence of earthquakes and volcanic activity to constructive and destructive plate boundaries
- Considering the role of heat energy and convection currents in the movement of tectonic plates
- Relating the extreme age and stability of a large part of the Australian continent to its plate tectonic history

Physical Sciences (part)
Energy transfer through different mediums can be explained using wave and particle models (ACSSU182)

- Exploring how and why the movement of energy varies according to the medium through which it is transferred
- Investigating the transfer of heat in terms of convection,…., and identifying situations in which each occurs
- Exploring the properties of waves, and situations where energy is transferred in the form of waves, such as sound and light

Year 9 WASP – Teacher Introduction

An initiative supported by Woodside and ESWA

Year 9 WASP – Teacher Introduction

Continental Drift and Plate Tectonic Theory

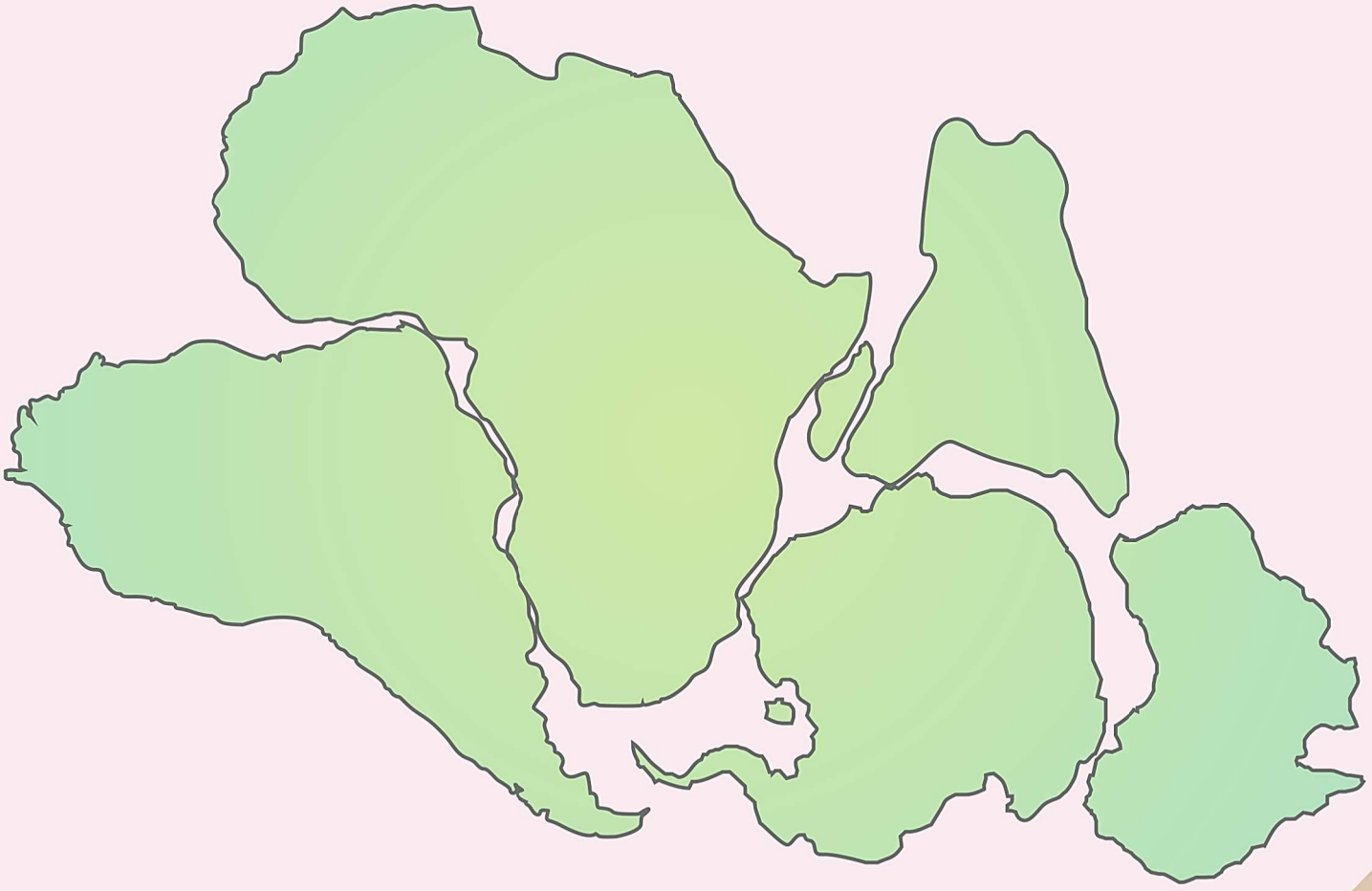
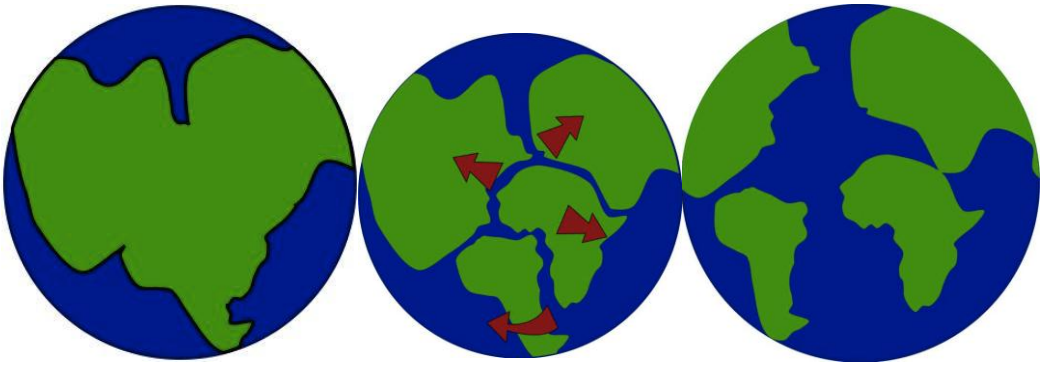


Plate Jigsaw - Teacher Notes



Supercontinent Pangaea Modern continents

Wegner was able to re-assemble the supercontinent Gondwana from clues found in geology, fossils, climate bands, magnetic orientation of rock and jigsaw fit of present continents. Many sources of evidence are often necessary to support new ideas. Nothing is ever proven in Science but hypotheses can be supported or disproved by evidence.

Science only accepts evidence (data) that is observable, measurable and repeatable.

Students are asked to reassemble a picture from clues. The original jigsaw may be made of bread, cake, cardboard or paper.

Activity **Bread jigsaw (putting it back together)**

Materials per student

- Old newspaper as a bench protector
- One slice of bread with the crusts cut off. A sandwich loaf usually has 24 slices. School canteens may save you “old” loaves that can then be frozen for this activity. The age does not matter as it will not be eaten

Plate Jigsaw - Teacher Notes

- Felt tip pens
- Tin lids, saucers
- PVA paint and paint brushes
- One plastic or paper sandwich bag. Sheets of newspaper can also be folded to make a bag for the painted slice

Place the bread slice on newspaper and draw/paint a simple picture or pattern on it.
Make sure the picture goes to the edges of the slice
Write your name on the bag, write a very simple description of the picture (three words or less) on the bag and place the bread slice on top for 5 minutes
(An unscrupulous teacher with an impatient class (me) wafted a hairdryer over the slices of bread for 3 minutes to dry the bread– It works! *Or*) Leave overnight to dry where your teacher indicates. (Out in the sunshine it will dry crisp in half a day. If the weather is wet you could also place in an oven at 100°C for one hour)
Break the slice into at least 8 pieces (about the size of your thumbnail) and return to the bag. These are the jigsaw pieces.
Gently shake the bag to mix up the pieces
Exchange your bag with another student and see if you can put the picture back together.

Draw the completed jigsaw picture below

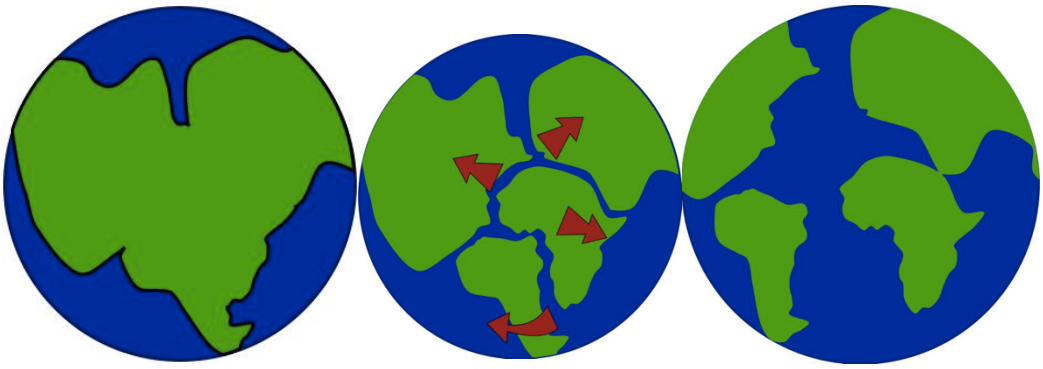
What clues did you use to put it all back together? Description on bag, painted side/blank side, corners, straight cut edges, colour masses, straight lines

Would it have been easy to reassemble the picture using only one of the pieces of evidence above? Explain your answer No. You need several clues to build up the whole picture

How good was your "fit". Pretty good but small pieces were missing

How did this activity resemble Continental Drift Theory? Many clues were needed to support the theory

Plate Jigsaw - Student Activity



Supercontinent Pangaea Modern continents

Wegner was able to re-assemble the supercontinent Gondwana using clues from geology, fossils, climate bands, magnetic orientation of rock and jigsaw fit of present continents.

Activity **Bread jigsaw (Putting it back together)**

Materials per student

- Old newspaper as a bench protector
- One slice of bread with the crusts cut off.
- Felt tip pens
- Tin lids or saucers for paint palettes
- PVA paint and paint brushes
- One plastic or paper sandwich bag

Place the bread slice on newspaper and draw/paint a simple picture or pattern on it.
Make sure the picture goes to the edges of the slice
Write your name on the bag, write a very simple description of the picture (three words or less) on the bag and place the bread slice on top
Leave overnight to dry where your teacher indicates.
Hold the dry bread inside the bag and break it into at least 8 pieces. These are the jigsaw pieces.
Gently shake the bag to mix up the pieces
Exchange your bag with another student and see if you can put each other's picture back together.

Plate Jigsaw - Student Activity

Draw the completed jigsaw picture below

What clues did you use to put it all back together?

1. _____
2. _____
3. _____
4. _____
5. _____

Would it have been easy to reassemble the picture using only one of the pieces of evidence above? Explain your answer.

_____

How good was your "fit"? _____

How did this activity resemble the development of Continental Drift Theory?

_____

_____

Many sources of evidence are often necessary to support new ideas. Nothing is ever proven in Science but hypotheses can be supported or disproved by evidence.

Science only accepts evidence (data) that is observable, measurable and repeatable

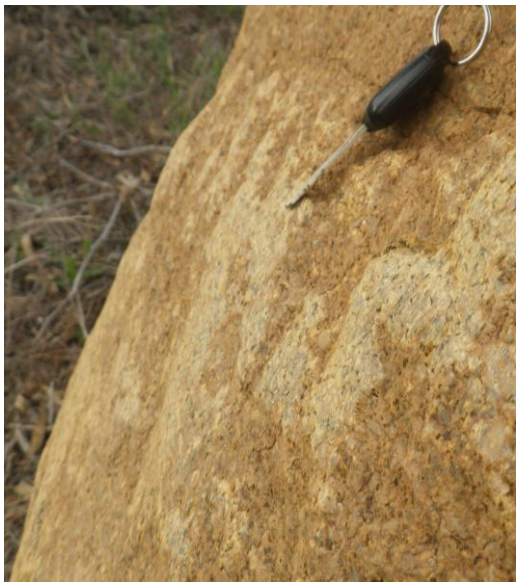
An initiative supported by Woodside and ESWA

Primary & Secondary Data Collection - Teacher Notes

Modern scientific theory relies on the collection of supporting data that is observable, measurable and repeatable. The explanations of how mountains were raised, volcanoes erupt and the Earth's surface changes have adjusted and improved over the years as more information (data) becomes available and technology improved.

Primary data is data collected by the observer such as measurement of the magnetic dip and orientation of rocks from India and Australia. In the picture, the rock in the geologist's hand is sufficiently magnetic to attract the swinging magnet. Since the geologist is collecting the data themselves, the data is primary

Secondary data uses observations collected by another. You can compare the photograph of Permian Gondwanaland leaf fossils (left) found in rocks near Mingenew in the Central Midlands of WA with the photograph of fossils from rocks of the same age (right) in Victoria. Since the photographer selected the information it is secondary data.



Proxy data uses data collected for another purpose from which i*nference* can be made. This photograph was made during a tourist trip near Coalseam Reserve in our Central Midlands of WA. The long parallel scrape marks apparent on the surface of this stone were probably caused by ice dragging it over others. They look like those seen elsewhere in the world where glaciers are presently retreating, dropping stones marked like these. Therefore it can be inferred that the Central Midlands must have been under ice and its rocks scraped by ice in the past. Furthermore, striae radiate outwards from the centre of an ice cap so the location of the South Pole can be inferred for that time.

Continental Drift Theory suggests that at various times the continents of Earth have come together to form supercontinents and then split up only to reassemble again later. Pressure on the crust when they moved together created mountains. Although some evidence to support this lay in the study of geology, palaeontology and geography much of early theory relied on inference. It wasn't until the 1950s that it was possible to collect primary data to support both the theory and to suggest the process that powered movement. The original concept developed into Plate Tectonic theory. More recent data from modern geophysics, radiometric dating, and satellite imaging can measure these changes. Our continents ***are*** moving and have done so over the last 3.8million years.

Early theories and beliefs to explain the formation of mountains
Explanations of how mountains were raised, volcanoes erupt and how the Earth's surface changes have been adjusted and improved over the years as more information (data) becomes available and technology improves.

Beliefs
Aboriginal people believed that dreamtime spirits shaped Earth's surface. Many stories tell of a rainbow serpent whose body made valleys and pushed up mountains as he moved across the land. Early European thinkers tried to relate Earth movements (diastrophism) to Noah's flood and other biblical events.

Which of the following theories relied on primary data, secondary data or proxy data?

In the 15th century, Giardano Bruno realised that had Earth cooled down after its initial molten phase. He proposed that mountains were wrinkles caused by shrinkage due to cooling. (He compared Earth to a dried apple).

Data type Proxy data. He used the apple to infer what may have happened to the Earth

In 1620 the English scientist Francis Bacon was reviewing early seafaring maps. He noticed that the coastlines of Africa and South America appeared to fit together.

Data type Secondary data. He used maps prepared by others

In 1668 Francis Plaget suggested that the continents had been torn apart by Noah's Flood which he had read about in the Bible.

Data type Belief/secondary

In 1830 Charles Lyell noted changes in historical sea level in the sunken temple of Seraphis when he visited it. His careful mapping outlined a series of rises in sea level. He suggested that sudden changes could make land rise or fall without breaking buildings.

Data type Primary

In 1832 on the second voyage of the Beagle, Charles Darwin viewed and mapped raised land terraces in South America and suggested that such rises were not sudden and local as Lyell had suggested but could happen over large geographic ages. Later climbing in the Andes he noted a fossilized forest and beach at 2,100m above sea level suggesting that great rises could occur.

Data type Primary

In 1885 Austrian geologist Edward Seuss noted similarities between plant fossils in the southern continents and gave the name Gondwanaland to the super continent to which they might have belonged.

Data type Primary (in fact Edward only had sample of the Australian plants so primary and secondary (South Africa and South America))

Wegner's Theory of Continental Drift

In 1915 Alfred Wegner blended ideas from previous thinkers with some of his own and published *Continental Drift Theory*. This suggests that at various times the continents of earth have come together to form supercontinents and then split up only to reassemble again later. He suggested there was one great super continent called Pangaea (all earth). Pangaea split into a northern continent, Laurasia and a southern continent Gondwana. These again split up about 60 million years ago to form smaller continents that moved slowly to their present day locations

You will be assembling his supporting data (evidence) and attaching it to this worksheet. This activity is based on maps downloaded from Earthlearning web site. http://www.earthlearning.com/search/.cgi?terms+Continental+Drift

1. Jigsaw fit of continental margins across the Atlantic. The fit is particularly close when the undersea continental shelf margins are used. Cut out along the east and west sides of the Atlantic Ocean and decide if the fit is sufficient to support Wegner's theory.

This evidence does/does not support Wegner's Theory of Continental drift because it infers that the two sides could have been joined together in the past.

2. Identical fossil plant and animal assemblages found on opposite sides of the Atlantic, as reported in many scientific papers, suggesting that the lands were joined. The southern continents could be re-assembled to form the supercontinent of Gondwanaland. (See second picture on first page)

Why did Wegner particularly select freshwater animals and land plants to use as evidence? Freshwater animals could not have survived in the sea. The lands must have been joined for them to have been spread across. Similarly, although it is possible for some seeds to drift across the sea, the width of the Atlantic and Indian oceans would have made this very difficult. Some opponents proposed thin land bridges which crossed the oceans.

This evidence does/does not support Wegner's Theory of Continental drift because It explains how such organisms could be identical across great stretches of ocean.

3. Reports of large-scale geological features that can be matched on either side of the Atlantic. E.g. The Karoo and Santa Catarina geological system

This evidence does/does not support Wegner's Theory of Continental drift because it demonstrates that identical climatic and geological processes were happening at the same time therefore they must have been close.

4. Evidence of glaciation in areas presently far away from the present poles. A "band" of glacial features such as U shaped valleys, drop stones and glacial moraines runs from South America, across central Africa, through North India and Southern Australia.

This evidence does/does not support Wegner's Theory of Continental drift because away from the poles glaciation only occurs in small patches on top of high mountains. These large glacial deposits suggest that all these areas must have been together near the pole.

5. Glacial scratches (striae) observed on rocks from the southern continents radiate out from a central point (South Pole) when the continents are fitted back together. (See third picture on first page)

This evidence does/does not support Wegner's Theory of Continental drift because present glaciers move away from the poles. As they move, the boulders they carry scratch rocks along their pathways. The marks of these scratches can be traced back to the heads of the glacier. If the continents were not together the marks do not make sense.

Given this evidence, would you have believed Wegner's theory? Explain your answer.
Any reasoned answer

Can you provide four pieces of scientific evidence to support the theory that you have been ***actively*** engaged in, in completing this worksheet. (***HINT OMMR***)

1. All the questions have been answered (observable, measurable)
2. I thought for myself and did not copy other's answers (observable)
3. I wrote all the answers myself/my handwriting (observable)
4. My reasons for each answer have been written (observable, measurable)
5. I have not left the room (observable)
6. I have/will have a good mark (observable, measurable)

Wegner's major weakness however was that he couldn't suggest a reasonable mechanism for driving continental movement and that his calculations for the rate of movement were too fast (250cm/year). He theorised that continents moved through the surface of Earth like giant snow ploughs under the gravitational influence of the Sun and Moon and "polar pull". Detractors suggested that land bridges had joined the continents allowing plants and animals to spread. Most particularly they mocked the ability of a meteorologist to understand geology.

By 1930 few geologists believed in Wegner's theory.

By the 1950s new technologies brought new evidence to support his theory and also suggest a better mechanism for moving continents. It was called Plate Tectonic Theory.

Modern scientific theory relies on the collection of supporting data that is observable, measurable and repeatable.

Primary data is data collected by the observer.
In the picture, the rock in the geologist's hand is sufficiently magnetic to attract the swinging magnet. Since the geologist is collecting the data themselves, the data is primary. Give your own example of primary data.

_____

_____

Secondary data uses observations collected by another. You can compare the photograph of Permian Gondwanaland leaf fossils (left) found in rocks near Mingenew in the Central Midlands of WA with the photograph of fossils from rocks of the same age (right) in Victoria. Since you used another's photographs it is secondary data.

Give your own example of secondary data _____

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Proxy data uses data collected for another purpose from which i*nference* can be made. This photograph was made during a tourist trip to Coalseam Reserve. The long parallel scrape marks apparent on the surface of this stone found in the Central Midlands of Western Australia look like those seen elsewhere in the world where glaciers are presently retreating, dropping stones marked like these. Therefore it can be inferred that the Central Midlands must have been under ice and its rocks scraped by ice in the past. Furthermore, striae radiate outwards from the centre of an ice cap so the location of the South Pole can be inferred for that time.

Give your own example of proxy data _____

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Data type _____

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Data type _____

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Data type _____

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Data type _____

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This evidence does/does not support Wegner's Theory of Continental drift because

_____

2. Identical fossil plant and animal assemblages are found on opposite sides of the Atlantic, as reported in many scientific papers, suggesting that the lands were joined. The southern continents could be re-assembled to form the supercontinent of Gondwanaland. (See second picture on first page)

Why did Wegner choose freshwater animals and land plants to use as evidence?

_____

_____

This evidence does/does not support Wegner's Theory of Continental drift because

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3. Reports of large-scale geological features that can be matched on either side of the Atlantic. E.g. The Karoo and Santa Catarina geological system.

This evidence does/does not support Wegner's Theory of Continental drift because

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4. Evidence of glaciation in areas currently far away from the present poles. A "band" of glacial features such as U shaped valleys, drop stones and glacial moraines runs from South America, across central Africa, through North India and Southern Australia.

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5. Glacial scratches (striae) observed on rocks from the southern continents radiate out from a central point (South Pole) when the continents are fitted back together. (See third picture on first page)

This evidence does/does not support Wegner's Theory of Continental drift because

_____

_____

Given this evidence, would you have believed Wegner's theory? Explain your answer

_____

_____

Can you provide four pieces of scientific evidence to support the theory that you have been actively engaged in, in completing this worksheet. (HINT OMMR)

_____

_____

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_____

Wegner's major weakness however was that he couldn't suggest a reasonable mechanism for driving continental movement and that his calculations for the rate of movement were too fast (250cm/year). He theorised that continents moved through the surface of the earth like giant snow ploughs under the gravitational influence of the Sun and Moon and "polar pull".

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By 1930 few geologists believed in Wegner's theory.

By the 1950s new technologies brought new evidence to support his theory and also suggest a better mechanism for moving continents. It was called ***Plate Tectonic Theory***.

Continental Drift – Review (Teacher)

There are twenty six words used to discuss continental drift in the puzzle below

T	M	F	I	G	T	D	E	D	T	V	Z	S	M	S
L	N	C	N	F	O	T	E	N	A	I	P	I	E	I
N	E	E	I	O	A	N	E	R	R	T	W	R	A	S
M	O	R	N	M	B	N	D	E	F	N	A	E	S	E
A	D	I	I	I	I	S	P	W	O	L	E	T	U	H
G	S	L	T	T	T	E	E	I	A	V	A	P	R	T
N	C	L	N	A	A	N	T	R	I	N	R	O	A	O
E	Y	O	I	T	I	A	O	D	V	I	A	S	B	P
T	C	R	A	S	T	C	E	C	M	A	K	S	L	Y
I	Z	B	O	N	S	N	A	A	R	C	B	O	E	H
C	L	I	E	E	C	O	R	L	O	E	V	L	P	T
E	T	I	F	E	H	Y	F	R	G	V	P	G	E	E
T	R	E	L	B	A	T	R	O	P	E	R	U	R	S
O	C	O	N	T	I	N	E	N	T	A	L	Y	S	T
S	E	C	O	N	D	A	R	Y	G	O	L	O	E	G

ALFRED (Wegner)
CLIMATE
CONTINENT
CONTINENTAL
DATA
DRIFT
EVIDENCE
FIT
FOSSILS
GEOLOGY
GLACIATION
GLOSSOPTERIS
GONDWANA
HYPOTHESIS
ICE
MAGNETIC
MEASURABLE
OBSERVABLE
ORIENTATION
PRIMARY
REPEATABLE
REPORTABLE
ROCKS
SECONDARY
SUPERCONTINENT
TEST
THEORY

Who proposed the theory of continental drift? Alfred Wegner

What does the theory of Continental Drift suggest? It suggests that our present continents were previously joined together to form a supercontinent. They have since broken apart.

What evidence supported this theory? Coastal fit, matching fossil assemblages, ancient climatic banding, matching geology/rocks, magnetic banding

What is the main problem with this theory? The mechanism for movement of continents didn't work.

The continent of Australia is moving northward at the same rate as your fingernails grow.

Continental Drift – Student Review

There are twenty six words used to discuss continental drift in the puzzle below.

T	M	F	I	G	T	D	E	D	T	V	Z	S	M	S
L	N	C	N	F	O	T	E	N	A	I	P	I	E	I
N	E	E	I	O	A	N	E	R	R	T	W	R	A	S
M	O	R	N	M	B	N	D	E	F	N	A	E	S	E
A	D	I	I	I	I	S	P	W	O	L	E	T	U	H
G	S	L	T	T	T	E	E	I	A	V	A	P	R	T
N	C	L	N	A	A	N	T	R	I	N	R	O	A	O
E	Y	O	I	T	I	A	O	D	V	I	A	S	B	P
T	C	R	A	S	T	C	E	C	M	A	K	S	L	Y
I	Z	B	O	N	S	N	A	A	R	C	B	O	E	H
C	L	I	E	E	C	O	R	L	O	E	V	L	P	T
E	T	I	F	E	H	Y	F	R	G	V	P	G	E	E
T	R	E	L	B	A	T	R	O	P	E	R	U	R	S
O	C	O	N	T	I	N	E	N	T	A	L	Y	S	T
S	E	C	O	N	D	A	R	Y	G	O	L	O	E	G

Who proposed the "Theory of Continental Drift" _____

What does the theory of Continental Drift suggest? _____

_____

_____

What evidence supported this theory? _____

_____

_____

What is the main problem with this theory? _____

_____

_____

The continent of Australia is moving northward at the same rate as your fingernails grow.

An initiative supported by Woodside and ESWA

Plate Tectonics - Teacher Background

The Theory of Continental Drift proposed that continents moved but did not suggest a convincing mechanism to power this movement. The Theory of Plate Tectonics builds on these earlier concepts and suggests how movement is maintained. Good general background information can be viewed on National Geographic's, "Colliding Continents" at www.youtube.com/watch?v=KCSJNBMOjJs

Scientific data recorded to support the theory that continents were moving apart:

1. **Discovery of mid-ocean ridges**

The possibility of undersea mountain ranges in the middle of the Atlantic Ocean was already suggested by readings from naval marine depth soundings. It was noticed that the ocean did not become deeper towards the centre. The presence of these ridges were later inferred when telephone lines were laid on the seafloor but shallowed markedly in the middle. However, when telephone and cable lines laid across oceans repeatedly snapped and had to be repaired it was suggested that this might be because they were being stretched. (This led to the "Expanding Earth" theory which as since been discounted).
Exploration of the ocean floor since the early 1950s gave us images of, and rock samples from, mid-ocean ridges, which have been found to spread 80,000km around the planet. These ridges are volcanically active producing iron rich rocks suggesting a source in the asthenosphere or mantle.

2. **Seafloor spreading at mid-ocean ridges and rock ages**

Further exploration along the Mid-Atlantic Ridge collected evidence that lavas spreading from a trench in the middle of the ridge were pushing older material apart. The lavas contained radioactive minerals that decayed at a known rate permitting their age since eruption to be estimated. Mirrored bands of rocks of the same ages were found to line up either side of the ridge with youngest rocks close to the ridge and ages increasing as you move away.

3. **Seafloor spreading and magnetic stripes**

Evidence was also collected from magnetic minerals in the lavas. Molten iron rich magma chills to rock on exposure to air or under the sea. In molten rock magnetic minerals align themselves to the poles. This orientation is "frozen" on crystallisation. New magma erupting from the ridge displaces earlier lava flows to either side of the spreading seafloor. Continuous eruptions leads to the formation of parallel bands of lava of the same age spreading outwards on either side of the ridge. Our magnetic poles constantly move and even "flip" occasionally. These parallel bands of polar orientation and reversal have been observed and measured in the rock.
Aside: Early in Earth's history planetary differentiation took place creating a crust, mantle and core. Less dense silica rich rocks form our outer lithosphere and iron and magnesium rich rocks increase towards the core. This concentration of iron and nickel is responsible for the creation of our magnetosphere. Earth's magnetic field is not constant.

4. **Satellite based measurements (GIS & GPS)**

Laser measurement from satellites has given us primary data on the relative movement of our present landmasses. Twenty four satellites circle the Earth. Each satellite has a computer, an atomic clock and a radio. More information and activities can be found at the IRIS website (http://www.iris.edu/hq/programs/education_and_outreach/animations/14)

This data suggests that continents "float" on denser oceanic crust. Oceanic crust is formed at mid-oceanic ridges

Scientific data recorded to support the theory that continental plates were converging:

1. Mountain ranges and gravity

Folding and faulting of sedimentary beds observed in many major mountain ranges appears to be the result of compression. Folded fossil beaches are found near the top of Mount Everest. This land must have been compressed and uplifted from sea level.
Scientists working in the Andes and in the Himalayas discovered that a pendulum would be attracted to large mountain ranges. This suggested that the mountains had a greater gravitational pull than the surrounding plains and that this must be because they had "hidden" mass. This mass of thickened continental crust forms a "keel" below the range and its mass attracts the pendulum.

2. Marine trenches

Marine exploration scientists also observed deep trenches along active volcanic continental margins. Ocean sounding using weights and cables has been superseded by LIDAR, an echo sounder which measures reflected light or sound. Trenches can be over 10km deep. Our knowledge of trenches is restricted by the paucity of surveyed areas.
It is suggested that trenches form where oceanic crust is being subducted under continental crust. This is supported by measurement of progressive low angle seismic activity zones leading away from the trench under the overriding plate. It is also supported by the presence of volcanic island arcs erupting lava whose composition reflects melted oceanic crust and sediments.

This data suggests that oceanic crust is recycled at plate margins and oceanic trenches.

Development of the theory
In 1958 Carey suggested that the lithosphere consisted of seven major tectonic plates and many minor ones. The lithosphere lies above the asthenosphere but is moved by convection currents in it. Where plates move apart there is a zone of divergence and new oceanic crust is formed. Where the plates move together there is a zone of convergence where deep oceanic trenches or mountain ranges can form. The edges of tectonic plates are associated with the production of violent geological events such as earthquakes and volcanoes.

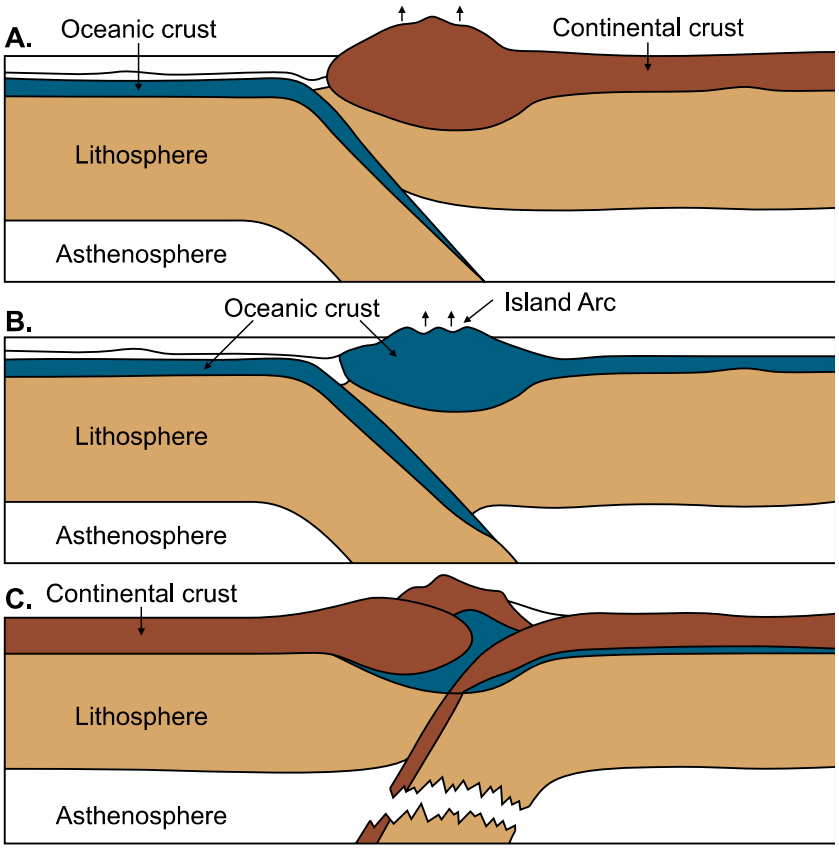


Diagram: Figure 13.19 (Exploring Earth & Environmental Science, Tompkins, 2010)

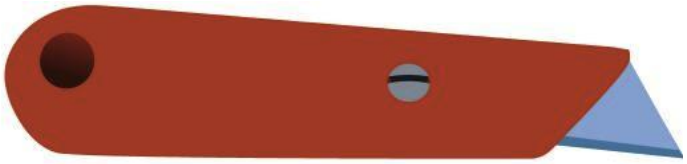
Plate Tectonics - Teacher Background

Plate Tectonic Theory suggests that:

1. ***The Earth's surface (lithosphere) is made of large plates.***
2. ***These plates move a few centimeters per year***
3. ***Convection currents in the underlying partially melted asthenosphere drive this movement.***
4. ***The convection currents are powered by heat from radioactive decay and slab pull from dense descending plates.***
5. ***The ocean floor is spreading from mid-oceanic ridges along zones of divergence.***
6. ***Plates can be brought together, moved apart or passed alongside each other.***
7. ***Plate margins are sites of intense geological activity such as earthquakes, mountain building, trench formation and volcanism.***

Seafloor Model - Teacher Notes

Evidence for seafloor spreading (Divergent plate boundary)
Where magma comes to the surface along mid-oceanic ridges the youngest rocks will be closest to the ridge and their age will increase as you move further away. Students are asked to create a simple model that replicates what happens when seafloor spreads and how that affects rock ages across the mid-oceanic ridge.



If the class is excitable it may be advisable to cut the side from the boxes and the three slits beforehand. Some students will need direction on how to use a "Stanley" or craft knife safely.

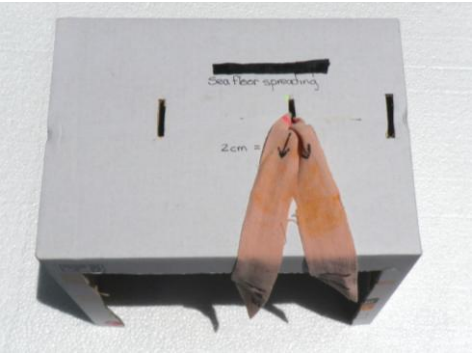
Cuts should not be made towards or close to the body
The blade should always be kept inside the haft when not in use.
The blade should never be used as a lever.

Materials per student or group

- A box large enough to get both hands inside (The boxes photocopy paper is delivered in are good however shoe boxes or tissue boxes can also be used)
- A Stanley knife or equivalent
- Two strips of paper about 50 cm long and 3cm wide. These can be cut from plain white or scrap paper. I used an old elastic bandage
- A stapler and sticky tape
- Four different coloured felt tip pens.

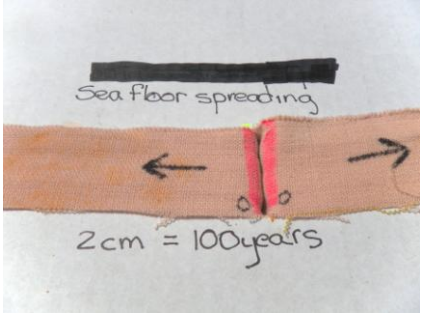
AIM **To model seafloor spreading**

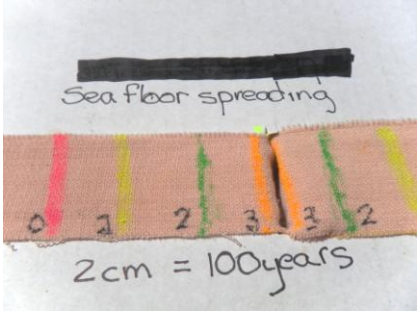
METHOD
Carefully remove one side of the box to permit access for your hands. If a margin is left around the gap the box will be stronger.
Cut three thin slits in the top of the box just a little wider than your strips of paper or other material (as per the photograph below).
Lead each strip down the central slit and down the slit near the edge.
Staple or stick each strip below to form two separate circular loops.
Ensure the joins hang well below the ocean floor.



Seafloor Model - Teacher Notes

The top of the box represents the ocean floor.
The central slit represents the mid-oceanic ridge where magma wells to the surface.
Pulling downward on the outer edge of each loop will cause material to rise from the ridge and spread.





Run the first felt tip pen down the central slit until a coloured band appears on both strips. Label this "zero".
Pull downwards on the outer edge of both loops until 2cm of tape has "erupted" on either side of the ridge.
Run the second felt tip pen down the central slit and label these 100 years on the strips.
Repeat moving the loops until all four colours have been used.

Draw a cartoon below of what happens each 100 years. Label the mid-ocean ridge and direction of movement.

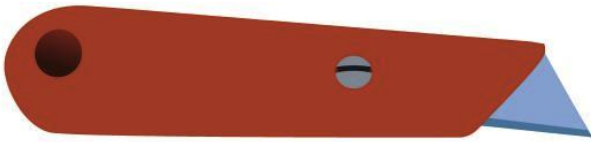
0 years	100 years	200 years	300 years	400 years

Describe the banding of the strips on either side of the mid-ocean ridge.
The banding on either side is a mirror image with the youngest rocks close to the ridge and aging away from it.
After 100 years, how much wider is the sea floor? 4cm
Does this activity model real seafloor spreading?
Yes it does as the crust is widened by each outpouring of molten rock from the mid ocean ridge
Is the ridge a zone of convergence (coming together) or divergence (moving apart)?
Divergence
Can we say ***new*** material is created at the ridge?
No because although it is newly crystallised rock, it is made from materials which have been recycled from elsewhere. Nothing is created or destroyed.

Seafloor Model - Student Activity

Evidence for seafloor spreading

Where magma comes to the surface along mid-oceanic ridges there are changes to the seafloor. Students are asked to create a simple model that replicates what happens here.



If your boxes have not been prepared for you, please write down safety considerations when using a craft knife

_____

_____

_____

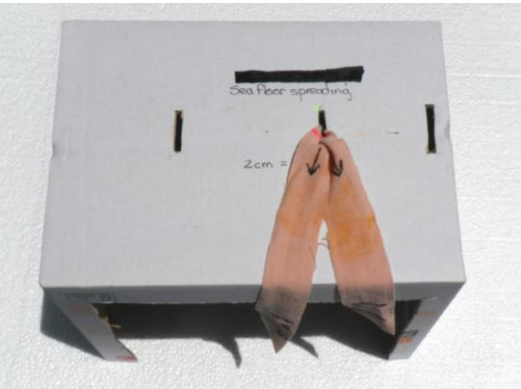
Materials per student or group

- A box large enough to get both hands inside
- A craft knife
- Two strips of paper about 50 cm long and 3cm wide.
- A stapler and sticky tape
- Four different coloured felt tip pens.

AIM **To model seafloor spreading**

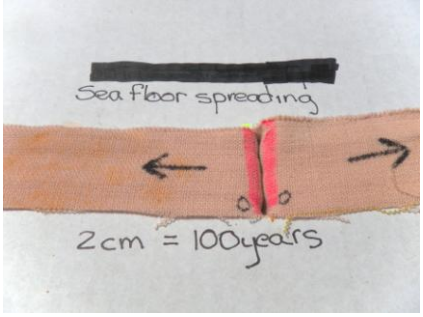
METHOD

Carefully remove one side of the box to permit access for your hands.
Cut three thin slits in the top of the box just a little wider than your strips of paper or other material (as shown in the picture below).
Lead each strip down the central slit and down the slit near the edge.
Staple or stick each strip below to form two separate circular loops.
Ensure the joins hang well below the ocean floor



Seafloor Model - Student Activity

The top of the box represents the ocean floor.
The central slit represents the mid-oceanic ridge where molten mafic magma rises to the surface.
Pulling downward on the outer edge of each loop will cause material to rise from the ridge and spread.



Run the first felt tip pen down the central slit until a coloured band appears on both strips. Label these "zero" as above.
Pull downwards on the outer edge of both loops until 2cm of tape/molten mafic magma has "erupted" on either side of the ridge.
Run the second felt tip pen down the central slit and label these 100 years on the strips.
Repeat moving the loops until all four colours have been used.

Results

Draw a cartoon below of what happens each 100 years. Label the mid-ocean ridge and direction of movement.

0 years	100 years	200 years	300 years	400 years

Conclusion and discussion

Describe the banding of the strips on either side of the mid-ocean ridge. _____

_____

After 100 years, how much wider is the sea floor? _____

Does this activity model real seafloor spreading? _____

_____

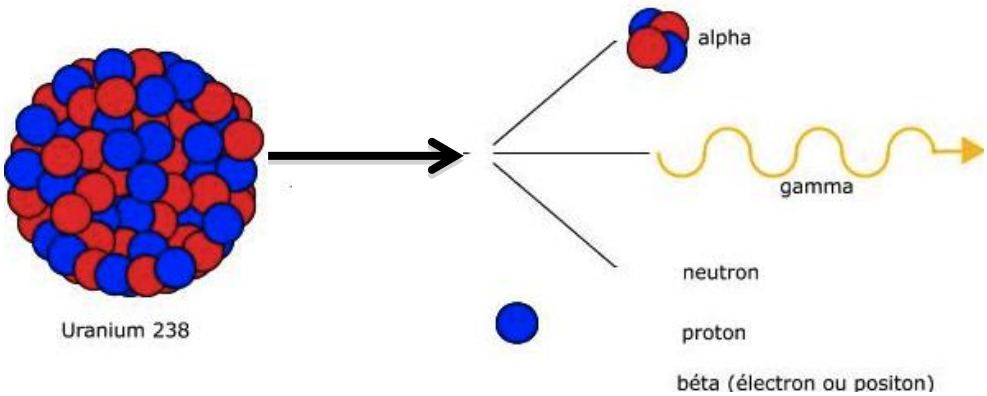
Is the ridge a zone of convergence (coming together) or divergence (moving apart)? _____

Can we say ***new*** material is created at the ridge? _____

Rock Age Data - Teacher Notes

Evidence for seafloor spreading

Part of the magnetic history of Earth is recorded in the basalts on either side of mid-ocean ridges. We can observe basalt flowing out from trenches at the centre of mid-ocean ridges. We can also estimate the ages of rocks using data from natural radioactive decay.



Earths crust is made of a silica rich continental crust layer that overlies denser iron and magnesium rich oceanic crust. Samples of deep ocean floor rocks show it becomes young towards mid-oceanic ridges. Oceanic floor is generally younger than continental crust. Continental crust can be up to 3.8 billion years old whilst the older sampled oceanic crust is only 350 million years old

Materials per student

- Sharp pencil (not HB) and eraser
- Ruler
- Calculator should not be necessary

When a rock solidifies its radioactive minerals start to decay. Radioactive minerals lose their radioactivity at a known rate. The time it takes to lose half their radioactivity is called their half-life. The mineral in this example is purely imaginary.
Plot the decay curve for radioactive mineral X on the graph paper provided below. Mineral X has a half-life of 100 years. Every 100 years its remaining radioactivity will be halved.
If its initial radioactivity is 80 units what will its radioactivity be in 600 years?

Calculations of radioactivity remaining

Time (years)	**Remaining radioactivity** (units)
0	80
100	40
200	20
300	10
400	5
500	2.5
600	1.25

Rock Age Data - Teacher Notes

Plot this radioactive data on your graph paper Graph paper provided on student worksheet.

HINT A graph needs: A title Change in radioactivity over time

1. The correct style of graph chosen. (Line or bar graph?) Line graph because it demonstrates how one piece of data (radioactivity) changes over another (time).
2. Its X and Y axes labeled including the correct units. X (horizontal) axis should be time in hundreds of years and the Y (vertical) axis radioactivity in units
3. Data points plotted in pencil Not HB
4. Data points joined to draw the graph Curved line
5. The graph should almost fill your sheet of paper

If the basalt has 15 units of radioactivity, how long ago was it erupted? 250 years ago

How many units of radiation would a basalt erupted 350 years ago have? 7.5 units

Can we estimate how much radiation a basalt erupted 1,000 years ago might have using this data? Explain your answer No we cannot extrapolate from the given data.

Can we use this method to age sedimentary rock formed under the ocean? No because sedimentary rock is formed from clasts (broken bits) of other rocks that have been weathered, eroded and deposited on the ocean floor. Any date given from individual clasts will represent the age of the original rock it broke away from.

How could the age of basalts flowing from mid oceanic ridges be used to demonstrate ocean floor spreading? If the floor of the ocean is spreading on either side of the ridge, the newest rocks will be close to the ridge and rocks will become progressively older the further away you get on either side of the ridge.

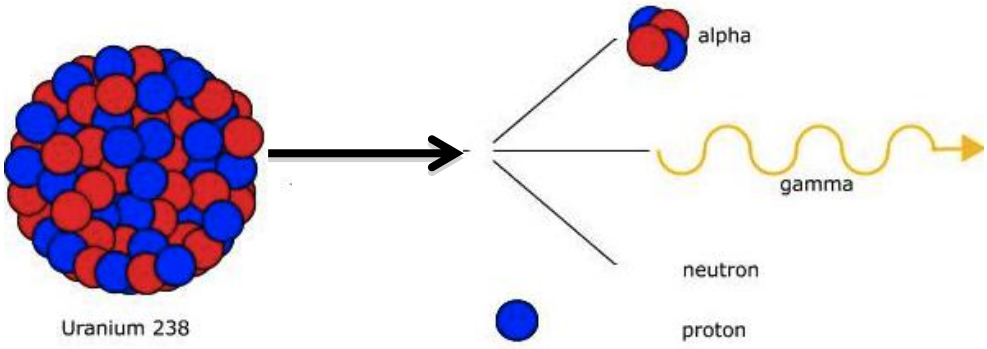
The present is the key to the past (James Hutton)

Pillow lava from Lake Ballard north of Menzies WA

This pillow basalt was erupted from the seafloor of what is now the Eucla Basin. We know it was erupted under water because of its classic shape. Volcanic material erupted under sea at present takes on a hard chilled margin as it comes in contact with cold water. Pressure inside builds up as more molten material is added and it bulges and rolls outward to take on the classic pillow shape.

Rock Age Data - Student Activity

Part of the geologically recent history of Earth is recorded in the basalts on either side of mid-ocean ridges. We can observe basalt flowing out from trenches at the centre of mid-ocean ridges. We can also estimate the ages of these rocks using data from natural radioactive decay. Decay starts as soon as the radioactive minerals become solid.



Materials

- Sharp pencil (not HB) and eraser
- Ruler

Not all rock-forming minerals are radioactive. When a rock solidifies its unstable radioactive minerals start to decay. They lose their radioactive energy at a known rate. The time it takes to lose half their radioactivity is called their half-life.

Plot the decay curve for radioactive mineral X on the graph paper provided. Mineral X has a half-life of 100 years. Every 100 years it remaining radioactivity will be halved.
If its initial radioactivity is 80 units calculate what its remaining radioactivity be in 600 years?

Calculations of radioactivity remaining

Time (years)	Remaining radioactivity (units)
0	80
100	
200	
300	
400	
500	
600	

Rock Age Data - Student Activity

Plate Tectonics

Plot this data on your graph paper

HINT A graph needs:

1. A title
2. The correct style of graph chosen. (Line or bar graph?)
3. Its X and Y axes labeled including the correct units
4. Data points plotted in pencil
5. Data points joined to draw the graph

Using your graph answer the following questions

If a radioactive mineral X in basalt has 15 units of radioactivity, how long ago was it erupted? _____

How many units of radiation would basalt erupted 350 years ago have? _____

Can we estimate how much radiation a basalt erupted 1,000 years ago might have using this data? Explain your answer

_____

Earth's Magnetosphere- Teacher Notes

Earth is surrounded by a magnetic field (magnetosphere) like a simple dipole (two pole) magnet. This can be inferred by its effect on magnetic materials and also by the deflection of cosmic radiation.

Artificially magnetised iron results from the alignment of the outer skin of electrons that surround its positive core. It occurs naturally as magnetite (Fe_3O_4). Magnetism can be induced in the laboratory by wrapping a sensitive metal with a coil carrying an electric current and conversely moving magnets can induce electric current in a wire. A magnetic field is the area of field around a magnet.

The magnetic field surrounding the Earth is probably the result of a different process. The outer layer of the core acts like a giant dipole magnet due to electric currents in the molten pressurized iron and nickel. This explanation is known as the ***"Dynamo Theory"***. The movement of its internal conductive plasma produces the Earth's magnetic field.

Because the conductive fluid dynamo that powers this field is quite "chaotic" both the Sun and Earth's fields are subject to polar wandering and polar reversals. The Sun's field reverses every eleven years and the Earth's poles reverse every 200,000 to 300,000 years. Interestingly our next reversal is overdue and is calculated to happen within the next 2,000 years.

Earth's magnetic field, or magnetosphere acts as a shield against cosmic radiation. It deflects the stream of charged particles emanating from the upper atmosphere of the Sun.

The molten iron rich rock, solidifying at the surface, takes on the orientation of the poles at the time of crystallisation.

Earth's magnetism and its effect on magnetite was used by early navigators. They would float fragments of magnetite (Fe_3O_4) on paper or parchment over a liquid and it would move to align with magnetic North. Since it helped "lead" them to where they wanted to go, magnetite's common name is "lodestone". Students may try this using a pin or needle inserted through paper. Paper increases the surface area of the needle, decreasing its pressure and maintaining surface tension. In time paper will absorb water, become denser and sink. The "Make Your Own Compass" activity explains this.

In Western Australia early explorers had problems with major iron rich rock formations deflecting their compasses. Indeed the presence of magnetite in some parts of the Goldfields makes compasses unusable. Later prospectors used this effect to delineate greenstone belts containing magnetite and pyrrhotite. They did not seek those minerals, rather the magnetically unresponsive gold which was often found with them. How Mount Magnet in the Goldfields got its name should be self-evident. The Surveyor Robert Austin noted in 1854 that a hill near the present town site had magnetic iron stone which played havoc with his compass.

Geophysicists use variations in the Earth's magnetic field to find ore deposits. They fly magnetometers over prospective areas. By raising the height of the magnetometers they can penetrate through our regolith (blanket soil) to the deeply buried ore deposits below.

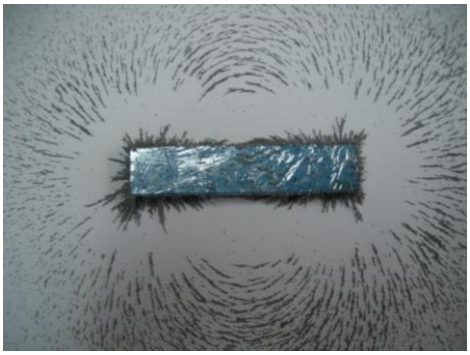
Earth's Magnetosphere- Teacher Notes

When magnetic minerals crystallise from molten magma they will align themselves with Earth's magnetic field at that time. Molten mafic magma such as basalt and dolerite will keep this imprint of the magnetic north pole until they re-melt. They register both the direction and dip. From this data both latitude and longitude of the place of crystallisation can be inferred.

Materials per student or group

- Two dipole bar magnets
- Scrap paper
- Kitchen plastic film (Glad wrap or equivalent)
- Iron filings (preferably in a shaker)

Wrap one magnet tightly with plastic.
Place on a piece of scrap paper.
Sprinkle iron filings across the magnet.
Observe and draw what you saw in the worksheet provided.

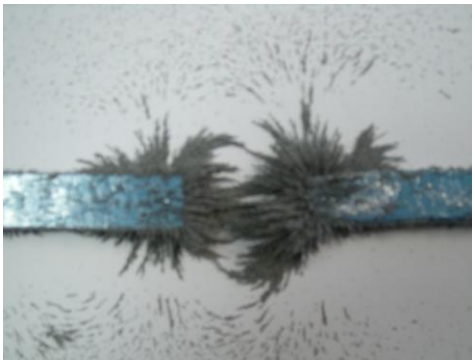


Magnetic field around a dipole magnet

Can you see the sphere of magnetism around the magnet? No. It can only be inferred by its effect on the iron filings.

Place another sheet of paper over the magnet and sprinkle filings over its surface.
What can you infer? Although you cannot see the magnet its presence can be inferred by the pattern of the iron filins.

Loosen the filings by unwrapping the magnet and retain the filings in the wrap.
Wrap both magnets.
Place magnets with like poles (N & N or S & S) 1cm apart and sprinkle with filings
Observe and draw what you saw in the worksheet provided.



Magnetic field around two like poles

Earth's magnetic field is not due to an internal magnet but is probably created by the rotation of the inner solid nickel iron core within the liquid outer core. Since the field is driven by movements in the core the magnetic poles are not in the same location as the geographic poles, wander and can even reverse, over time.

Interesting Fact: When working near the magnetic poles, a simple compass is not used as the declination of the needle towards the centre of the Earth is too steep to permit free rotational movement.

Earth's Magnetosphere- Teacher Notes

Interesting Fact: Magnets were called 'lodestones' because they could lead you to the correct path by pointing north.

How do the magnetic poles differ from the geographic poles?

Geographic poles are stationary and indicate 0^0 latitude. They do not reverse or "wander".

Magnetic poles move because of changes in the Earth's core and as a result of earthquakes. They wander and reverse.

EXTENSION

Approach one magnet with the like pole of another magnet.

I observed the magnets felt forced apart

Then approach one magnet with the opposite or unlike pole of another magnet.

I observed the magnets felt pulled together

Rules for magnets

LIKE POLES (N and N or S and S) repel

UNLIKE POLES (N and S) attract

Legend has it that the Greek scientist Archimedes used lodestone to pull nails from enemy ships and sink them! Do you think this is true? No he would need to have an extremely strong magnet. I have tried this repeatedly with iron nails hammered into pine and it did not work

Is the magnetosphere spherical? No because it forms a long tail pointing away from the Sun because of the "solar wind" a stream of photons blasted out from the sun.

Earth's Magnetosphere- Student Activity

Magnetic fields around poles or magnetospheres

Earth is surrounded by a magnetic field (magnetosphere) like a simple dipole (two pole) magnet.

Materials per student or group

- Two dipole bar magnets
- Scrap paper
- Kitchen plastic film (Glad wrap or equivalent)
- Iron filings (preferably in a shaker)

Method

1. Wrap one magnet tightly with wrap.
2. Place on a piece of scrap paper.
3. Sprinkle iron filings across the magnet.
4. Draw what you observed below

Magnetic influence around one dipole magnet

Can you observe the sphere of magnetism around the magnet? Explain your answer.

_____

_____

Place another sheet of paper over the magnet and sprinkle filings over its surface.
What can you infer?

_____

_____

_____

Earth's Magnetosphere- Student Activity

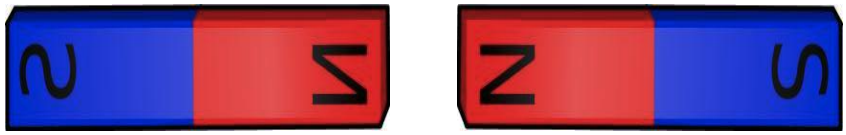
Magnetic influence between two opposing dipole magnets

Materials per student or group

- Two dipole bar magnets
- Scrap paper
- Kitchen plastic film (Glad wrap or equivalent)
- Iron filings (preferably in a shaker)

Method

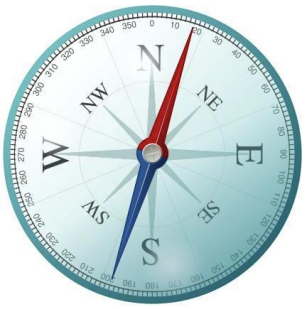
1. Separately wrap both magnets tightly with plastic.
2. Place 1cm apart with North Pole facing North Pole on a piece of scrap paper
3. Sprinkle iron filings across the magnets.
4. Observe and draw what you saw below.



Earth's magnetic field is not due to an internal magnet but is probably created by the rotation of the inner solid nickel iron core within the liquid outer core. Since the field is driven by movements in the core the magnetic poles are not in the same location as the geographic poles, wander and can even reverse, over time.

Interesting Fact: Magnets were called 'lodestones' because they could lead you to the correct path by indicating north.

How do the magnetic poles differ from the geographic poles?



_____

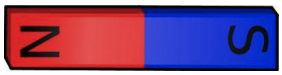
_____

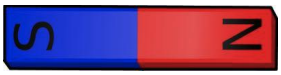
_____

_____

Earth's Magnetosphere- Student Activity

Interesting Fact: When working near the magnetic poles, a simple compass will not work as the declination of the needle towards the centre of the Earth is too steep to permit rotational movement.





Approach one pole of a magnet with the same pole of another magnet (north with north or south with south).

I observed _____

_____

Then approach one magnet with the opposite or unlike pole of another magnet.

I observed _____

_____

The rules for magnets are:

LIKE POLES (N and N or S and S) _____

UNLIKE POLES (N and S) _____

History tells that the Greek scientist and philosopher Archimedes used magnets to pull out the nails of attacking warships. Do you think this is true?

_____

_____

_____

Are magnetospheres spherical? _____

Magnetic Stripes - Teacher Notes

Part of the magnetic history of Earth is recorded in the basalts poured out on either side of mid-ocean ridges. We can observe basalt flowing out from trenches at the centre of mid-ocean ridges. At the time when the flow solidifies the magnetic minerals within align with the North Pole (See activity on Earth's Magnetosphere). Scientists have noticed that some rocks demonstrate reversed polarity. When the magnetic orientation of these basalts was measured across a mid-ocean ridge they were seen to be mirror images. When the ages of these bands were estimated they also were mirror images

Materials per student or group

- Two books
- Two sheets of lined paper
- Pen/pencil
- A coin

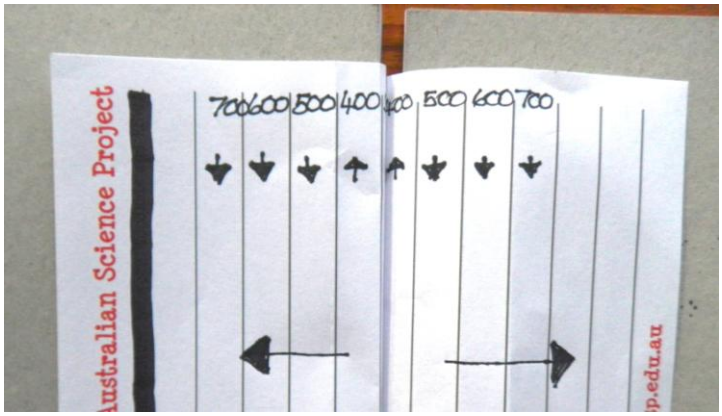
Mark one central line on the paper to represent the present.
Each line on either side represents 100 years of seafloor spreading basalt flows.

700 600 500 400 300 200 100 0 100 200 300 400 500 600 700

Toss a coin to decide whether the magnetic orientation of each of the seven one hundred year sections will be north or south.

Indicate with arrows which direction north lies on the paper. For each of the 7 sets of 100 years

Cut the paper in half along the "present" column.



Tuck the sheets under the books so that only a little protrudes at the centre. The books represent continental plates being pushed apart and the paper the lava flows coming out of the mid-ocean ridge.
Draw out the paper from between the books and see how the magnetic striping can be modelled.

Does this activity prove the theory of seafloor spreading? This does not support the theory, only models the possible process. Science requires data to support theories.

Every so often convection currents in our outer magnetic core change causing our poles to "flip". North becomes south. When the polarity of minerals is oriented to the North Magnetic pole we call it "NORMAL POLARITY". Normal polarity is usually represented by the colour white. When

Magnetic Stripes - Teacher Notes

Minerals' north poles are oriented towards the present South Magnetic Pole we call it "REVERSE POLARITY". Black usually represents reverse polarity.
The strip below represents polarity across a theoretical mid-oceanic ridge. Each block represents 100 years.

Present

What is the polarity at present? Reverse Polarity

How many years does the data cover? 350 years
If every block represents 100 years how many changes of polarity have happened in the last 350 years? Two, reverse to normal and then back again.

Use the following data to create a similar strip for a mid-oceanic ridge. Data is sourced from "Scripps Classroom Connections 2010. Activity - Solid Earth and Plate Tectonics by Leah Zeigler and Dave van Dusen. Normal polarity rocks have positive VPG latitude.
HINT Every time the VPG latitude crosses zero it is the result of a change in polarity.

Materials per student

- Paper
- Ruler
- Pencil/pen

Distance from ridge (km east)	VPG Latitude (deg.)
-156	82.9
-133	-88.5
-125	-80.5
-109	71.1
-85	-82.9
-76	12.7
-52	38.8
-39	86.9
-19	82.2
-8	60.4
Distance from ridge (km west)	VPG Latitude (deg)
10	58.4
21	84.0
38	87.4
60	40.2
76	9.6
87	-83.2
111	69.7
128	-78.8
136	-87.8
159	81.3

Magnetic Stripes - Teacher Notes

What is obvious about the stripes you have plotted? They are mirrored on either side of the central point. They are symmetrical.

Does this magnetic stripe data support the theory of seafloor spreading? Yes.

Extension Teacher may ask students to graph the VPG Latitude (degrees) against Distance from Oceanic Ridge (km). There is no regular pattern of period length for normal or reversed polarity. They vary for 0.1 and 1 million years. The last major period was 780,000 years ago when humans were present. There was however a brief reversal during the most recent glacial period about 41,000 years ago. There does not appear to be a direct relationship between polar reversals, global extinctions or warming/cooling periods. Our modern world depends on our magnetosphere for communications and navigation. Studies of rocks 200 million years and older has suggested that reversals are more common recently.

Magnetic Stripes – Student Activity

We can observe basalt flowing out from trenches at the center of mid-ocean ridges. At the time when the flow solidifies the magnetic minerals within align themselves with the North Pole. Scientists have noticed that some rocks demonstrated reversed polarity.

Materials per student or group

- Two books
- Two sheets of lined paper
- Pen/pencil
- A coin

Method

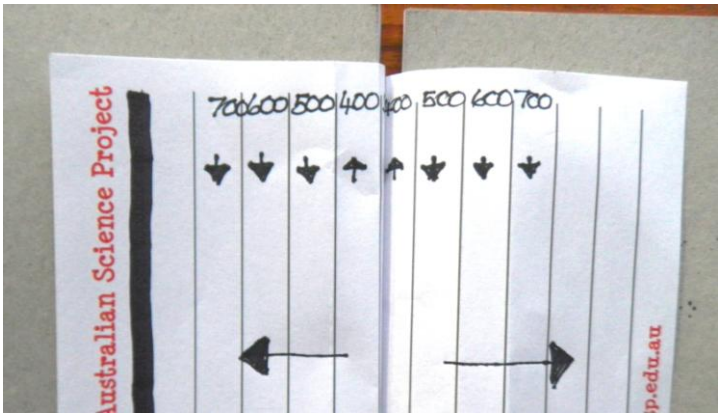
Mark one central line on the paper to represent the present. Each line on either side represents 100 years.

700 600 500 400 300 200 100 0 100 200 300 400 500 600 700

Toss a coin to decide whether the magnetic orientation of each of the seven one hundred year sections will be north or south.

Indicate with arrows which direction north lies on the paper. For each of the 7 sets of 100 years

Cut the paper in half along the "present" column.



Wrap the sheets of paper round the books so that only a little protrudes. The books represent continental plates being pushed apart.

Draw out the paper from between the books and see how the magnetic striping can be modelled.

Does this activity prove the theory of seafloor spreading?_____

_____

Magnetic Stripes – Student Activity

Every so often convection currents in our outer core change and our poles "flip". The North Pole becomes the South Pole. When the polarity of minerals is oriented to the North Magnetic pole, this is termed "***NORMAL POLARITY***". Normal polarity is usually represented by the colour ***white***.
When it is oriented towards the present South Magnetic Pole this is termed "***REVERSE POLARITY***". The colour **black** usually represents reverse polarity.

The strip below represents polarity in basalt across a theoretical mid-oceanic ridge

Present

What is the polarity of rocks extruded at present? _____

How many years does the data cover? _____

If every block represents 100 years how many changes of polarity have happened in the last 350 years?

_____

Use the following page's data can be used to create a strip across a mid-oceanic ridge. Normal polarity rocks have positive VPG latitude.

HINT Every time the VPG latitude crosses zero is a change in polarity.

Materials per student

- Paper
- Ruler
- Pencil/pen

What do you notice about the stripes you have plotted? _____

_____

Does this magnetic stripe data support the theory of seafloor spreading? Explain your answer.

_____

_____

_____

_____

Data to support the hypothesis of seafloor spreading

Distance from ridge (km)	VPG Latitude (deg.)
-156	82.9
-133	-88.5
-125	-80.5
-109	71.1
-85	-82.9
-76	12.7
-52	38.8
-39	86.9
-19	82.2
-8	60.4
Distance from ridge (km)	VPG Latitude (deg)
10	58.4
21	84.0
38	87.4
60	40.2
76	9.6
87	-83.2
111	69.7
128	-78.8
136	-87.8
159	81.3

Make Your Own Compass – Teacher Notes

We can find our way using a compass, a map or street directory or even an app in our mobile phone.

How else can you tell where North is? Bush wise students can also tell North by the Sun and shadows, the stars and using the hands of their watches

Navigators and adventurers such as Genghis Khan used to find their way by floating a magnetised needle on a piece of paper or parchment on a dish of water. As long as the paper remains dry the needle will respond to the lines of magnetic force generated from the Earth's core. It will always align North/South.

Temporary magnetism can be induced by stroking a metal object with a bar magnet. The needle should be stroked in one direction only. The magnet will align the outer electron "sea" of the metal.

AIM **To make a simple compass**

MATERIALS per student or group

- A pin or safety pin
- A small piece of paper
- A beaker half full of water or half a Petri dish full of water
- A bar magnet
- Masking tape
- Thread

METHOD

1. Half fill the beaker with water.
2. Thread the pin through the paper.
3. Gently stroke the pin twenty times with the bar magnet.
4. Let your needle float and note the direction to which it points.
5. Turn the beaker through 90 degrees and note what happens.
6. Turn through a further 90 degrees.

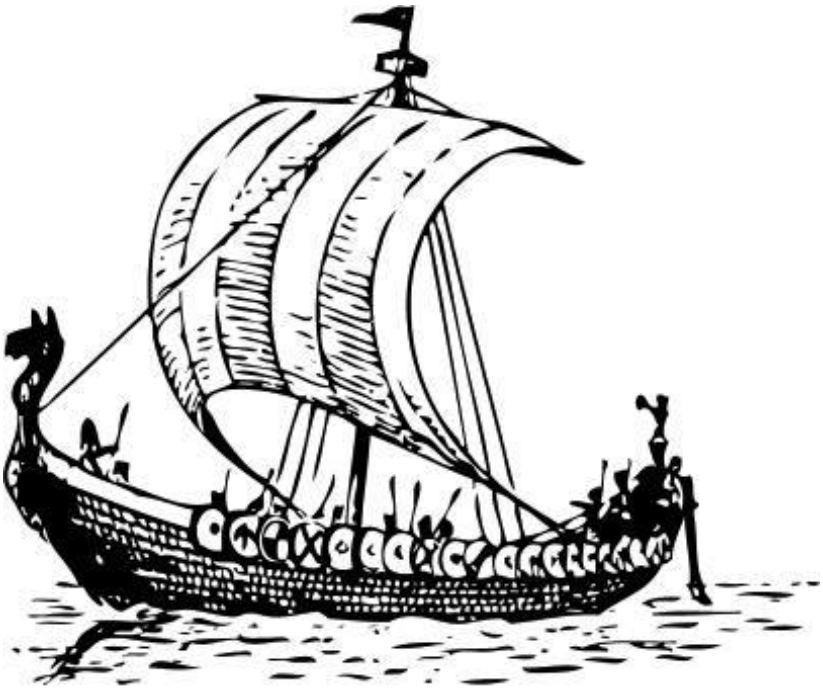
OBSERVATIONS

First position	Turned through 90^0	Turned further 90^0
		

What happened to the magnetised needle when the beaker of water was rotated?

The beaker rotated but the needle maintained its alignment

Explain why we had to push the needle throught the paper. A metal needle will sink if placed on water. It is denser than water. The paper increased the apparent surface area of the needle to decrease its pressure on the surface of the water. Surface tension was maintained and the needle was able to float.



Early seafarers used this technique to find magnetic North and calculate their direction of travel. They used a magnetised piece of metal or a piece of the mineral magnetite. The device was called a lodestone (leading stone)

Extension

By measuring the orientation of magnetic minerals in rocks we can locate the position of the poles at the time they crystallised.

Our magnetic poles are not the same as our fixed geographic poles. Magnetic poles "wander" in loops of about 80 km a day. Presently our "North Pole" has changed position by 1120km over the last 150 years. Interestingly out poles have "flipped" over hundreds of times in our geological past, most recently during the Stone Age about 780,000 years ago and there is some evidence we may be entering another reversal. The exchange of North and South poles takes between 1,000 and 10,000 years to occur. These events have been mapped and no relationship between them and catastrophic events such as extinctions has been noted. NASA has modelled the effect on our magnetosphere, which shields Earth from cosmic radiation, because any change in the magnetosphere would affect global communications. Interested students may wish to research "The Carrington Solar Storm"

The recent Aceh earthquake caused measurable movement of both our axis and magnetic poles.
The Sun's magnetic poles flip every 9 to 12 years.
Information on Polar Reversals can be found at:
http://www.livescience.com/18426-earth-magnetic-poles-flip.html

Make Your Own Compass – Student Activity

Earth's magnetism and its affect on rocks can help us understand continental plate movement

If free to move, magnetic material will always align North/South. Navigators used to find north by floating a magnetised needle on a piece of paper or parchment on a dish of water. As long as the paper remains dry the needle will respond to the lines of magnetic force generated from the Earth's core. North can also be found by using a compass, a map or street directory or an app.

Do you know any other ways of finding magnetic north? _____

_____

Temporary magnetism can be induced by stroking a metal object with a bar magnet

AIM **To make a simple compass**

MATERIALS per student or group

- A pin or safety pin
- A small piece of paper
- A beaker half full of water or Petri dish full of water
- A bar magnet
- Masking tape
- Thread

METHOD

1. Thread the pin through the paper.
2. Gently stroke the pin twenty times with the bar magnet. ***NOTE always stroke in the same direction.***
3. Let your needle and paper float and note the direction to which it points.
4. Turn the beaker through 90 degrees and note what happens.
5. Turn through a further 90 degrees.

RESULTS

First position	Turned through 90^0	Turned through 90^0

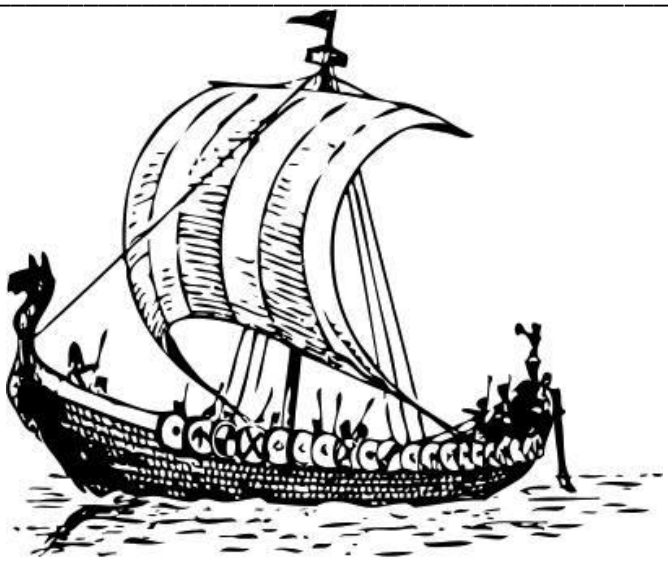
What happened to the magnetised needle when the beaker of water was rotated?

_____

Explain why we had to push the needle through paper._____

_____

_____



Early seafarers used this technique to find magnetic North and calculate their direction of travel their direction of travel. They used a magnetised piece of metal or a piece of the mineral magnetite. The device was called a lodestone (leading stone)

Extension

By measuring the orientation of minerals in some rocks we can locate the position of the poles at that time and whether they were north poles or south poles.

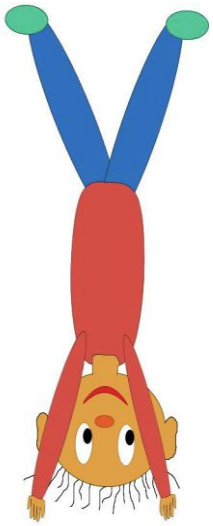
Our magnetic poles are not the same as our fixed geographic poles. Magnetic poles "wander in fixed paths. Interestingly out poles have "flipped" over hundreds of times in our geological past, most recently during the Stone Age about 780,000 years ago and there is some evidence we may be entering another reversal. The exchange of North and South poles takes between 1,000 and 10,000 years to occur. These events have been mapped and no relationship between them and catastrophic events such as extinctions has been noted. NASA has modelled the effect on our magnetosphere, which shields Earth from cosmic radiation, because any change in the magnetosphere would affect global communications. Interested students may wish to research "The Carrington Solar Storm".

The Sun's magnetic poles flip every 9 to 12 years.

Information on possible side effects of pole exchange can be found at:
http://www.livescience.com/18426-earth-magnetic-poles-flip.html

Polar Reversal - Student Activity

What happens when the poles flip?



If the poles flip (polar reversal) will our world be turned on its head?

You are asked to give a short one page scientific report on what will happen to life on Earth during the next polar reversal. Scientists have been measuring our magnetic field over the last 200 years and it has definitely been weakening. This weakening usually precedes polar reversal.

Your report should answer the following questions:

1. What creates the magnetic field around Earth? (3 marks)
2. Is having a magnetic field (magnetosphere) a good thing? Explain your answer. (3 marks)
3. What happens during polar reversal (1 mark)
4. What will be badly affected by polar reversal? Explain your answer (4 marks)
5. Are we all in danger? (2 marks)

Hints

Do not rely on only one source of information and select them carefully.
A diagram or sketch is easier to understand if it is clearly annotated.
Take rough notes and collect information for your bibliography.
Use words/vocabulary that are scientific and demonstrate your understanding well.
Don't leave it to the last minute.

Vocabulary (Fill in your vocab.)

Magnetosphere

Magnetic pole

This work is due on

_____

Plate Tectonics Evidence

M	N	M	M	C	E	M	Z	S	J	A	O	D	R	E
S	A	A	I	O	W	R	S	H	E	C	T	O	H	C
C	N	G	D	N	S	I	C	I	E	G	O	A	W	N
I	E	M	N	V	M	N	A	A	T	L	D	D	D	E
E	T	A	W	E	E	I	N	S	F	E	I	I	S	D
N	L	H	V	R	T	I	N	A	E	V	N	R	R	I
C	O	X	T	G	C	O	E	E	E	P	E	G	N	V
E	M	E	T	E	W	S	S	R	R	V	I	O	A	E
G	N	I	D	N	A	B	G	P	E	A	R	R	A	M
G	E	D	W	C	X	E	O	R	H	T	L	A	T	X
P	L	A	T	E	N	U	M	W	H	E	D	S	G	S
U	O	P	M	C	O	M	P	A	S	S	R	O	B	E
N	P	L	E	O	S	C	I	N	O	T	C	E	T	N
U	P	O	L	A	R	I	T	Y	H	T	U	O	S	A
T	C	E	L	F	E	D	F	L	I	P	Z	F	G	M

AGE
BANDING
COMPASS
CONVERGENCE
DATA
DEFLECT
DIVERGENCE
EVIDENCE
FLIP
MAGMA
MAGNETISM
MAGNETOSPHERE
MID
MINERALS
MOLTEN
NORTH
OCEANIC
PLATE
POLARITY
POLE
REVERSE
RIDGES
SCIENCE
SEAFLOOR
SOUTH
STRIPES
TECTONICS
TRENCH

Draw a diagram to show what happens if plates converge or diverge.
What are the three main pieces of evidence for seafloor spreading?

1. Visual data from mid ocean ridges
2. Magnetic striping on either side of the mid ocean ridges
3. Age of rocks increasing on either side of mid ocean ridges
4. Continental divergence data from global information systems (GIS)

What did you enjoy most in these activities?

Plate Tectonics Evidence

M	N	M	M	C	E	M	Z	S	J	A	O	D	R	E
S	A	A	I	O	W	R	S	H	E	C	T	O	H	C
C	N	G	D	N	S	I	C	I	E	G	O	A	W	N
I	E	M	N	V	M	N	A	A	T	L	D	D	D	E
E	T	A	W	E	E	I	N	S	F	E	I	I	S	D
N	L	H	V	R	T	I	N	A	E	V	N	R	R	I
C	O	X	T	G	C	O	E	E	E	P	E	G	N	V
E	M	E	T	E	W	S	S	R	R	V	I	O	A	E
G	N	I	D	N	A	B	G	P	E	A	R	R	A	M
G	E	D	W	C	X	E	O	R	H	T	L	A	T	X
P	L	A	T	E	N	U	M	W	H	E	D	S	G	S
U	O	P	M	C	O	M	P	A	S	S	R	O	B	E
N	P	L	E	O	S	C	I	N	O	T	C	E	T	N
U	P	O	L	A	R	I	T	Y	H	T	U	O	S	A
T	C	E	L	F	E	D	F	L	I	P	Z	F	G	M

Find 28 words used when presenting data (evidence) of seafloor spreading in the word sleuth above.

Draw a diagram which shows what happens when plates converge and diverge

What are the three main pieces of evidence for seafloor spreading?

1. _____

2. _____

3. _____

What did you enjoy most in these activities? _____

Folding & Faulting - Teacher Background

The crust of Earth is under continuous pressure from rising molten asthenosphere at mid ocean ridge divergence, from down dragging slabs of crust at zones of convergence and from the growing mass of sediments accumulating in basins.

Although stresses are greatest at the edges of continental plates, the whole fabric of the plate must make adjustments to these pushes and pulls. The Australian plate is presently sliding northwards under the Asian plate and growing larger through ocean floor spreading to the east, south and west margins.

Competence is a measure of resistance of rocks to deformation. Competent rocks will break or fault while incompetent rocks will bend or fold. Competence is affected by heat and pressure. E.g. limestone at the surface will fault whilst deeper in the crust it will fold. Igneous rocks tend to be more competent than sedimentary rocks because their crystals interlock making them more rigid.

Folded incompetent Hamersley Formation sediments at Hamersley Gorge.

When rocks fold downwards they create **synclines** and when they form domes we call these **anticlines**. Anticlines are important in the oil and gas industry because they can be traps.

Hint You can remember which way a syncline folds because "Sinners go down to Hell!"

Folding results in shortening and thickening of the Earth's crust. It creates mountains . Folding can be modelled by pressing the ends of layers of plasticine or cloth. Australia is fortunate not to lie on the active edge of a crustal plate. It is therefore less likely to suffer catastrophic earthquakes as plates that are folded, faulted and subducted. Pressure on plate margins however stresses all parts of the plate to a lesser degree. This is often released by reactivating old fault lines. Many of our faults are in a semi-continuous state of movement resulting in tiny imperceptible earthquakes.
www.ga.gov.au/earthquakes/staticPageController.do?page=earthquake-activity

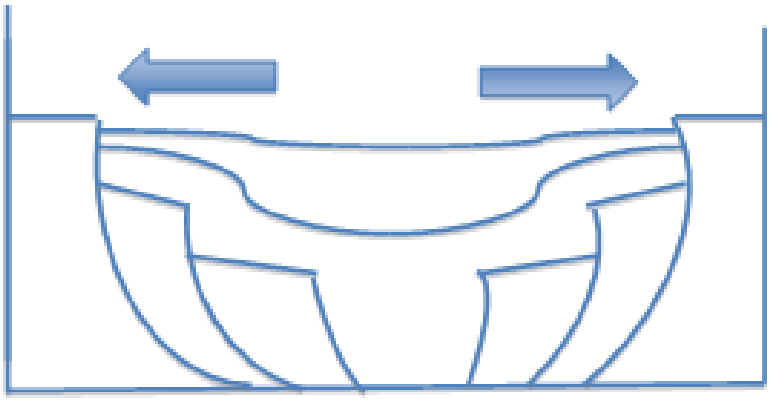
Faults are breaks in rock where one side is displaced from the other. Fault displacements can be on any scale from millimetres to kilometres. The picture is of fault displacement of a competent dolerite dyke in less competent gneiss. Major fault lines define the Yilgarn and Pilbara Cratons, the Stirling Ranges and most of the underlying geology of our state. The Darling Fault runs over 1,000km north to south defining the western edge of the Yilgarn Craton. The western side has been down-faulted over 15km in many small movements over millions of years.

Offshore faults also define the northern and western boundaries of oceanic and continental crust. Geological maps of our state can be obtained from http://www.dmp.wa.gov.au/7818.aspx and indicate many of the major faults lines in Western Australia. The Darling and Fraser fault systems have a major impact on our geography and land use

Normal faults result in extension
Reverse faults result in contraction
Where the crust is being sheared and blocks move laterally, transverse faults occur.

Where the crust is being stretched or extended "normal" faults occur. During ancient geological times Australia, India, Africa, New Zealand and Antarctica were welded together to form the supercontinent of Gondwanaland. About 184 million years ago the supercontinent began to break up and the present continental plates started to move apart. Continental crust between the separating plates was stretched thin and was split by a series of faults. The stretched crust then sagged to create a marine sedimentary basin.

WEST EAST

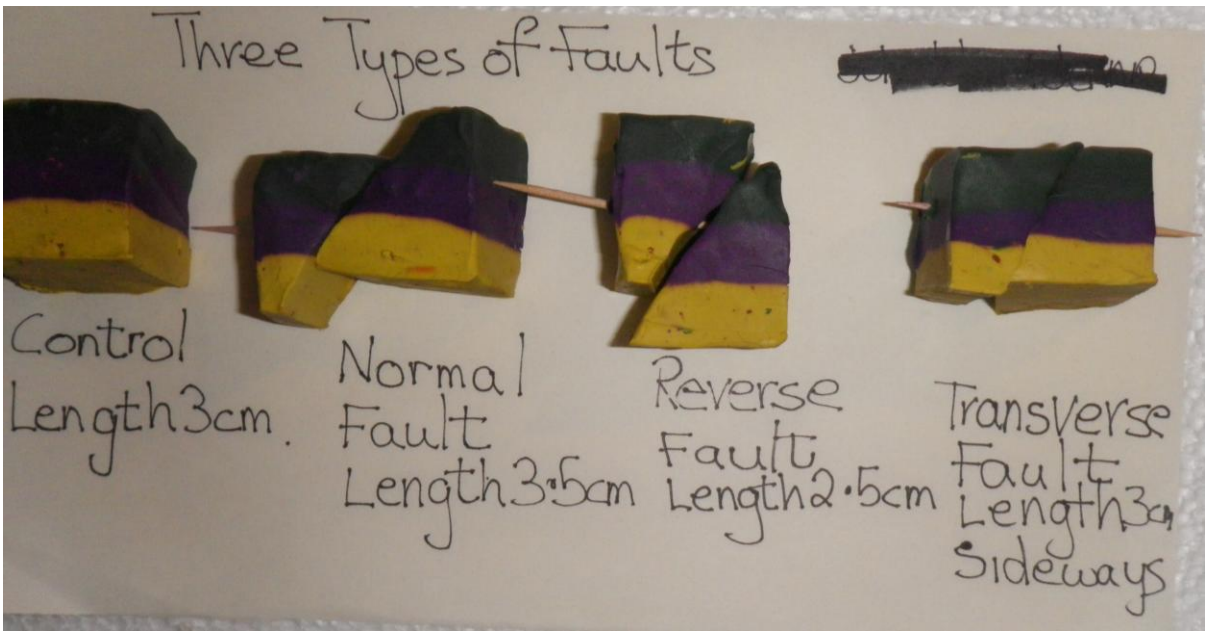


Where the crust is being compacted and blocks are slipping over and under each other "reverse" faults occur. Reverse faulting is responsible for throwing up the Southern Alps in New Zealand where the Australian and Pacific plates converge.

This picture is of a transverse fault in banded gneiss.
The major fault running through New Zealand also has a transverse movement. This is responsible for many earthquakes.

Of course food cannot be eaten in the laboratory. Folding and faulting activities can however be a great excuse for using cakes and sandwiches outside.

Three Types of Fault - Teacher Notes

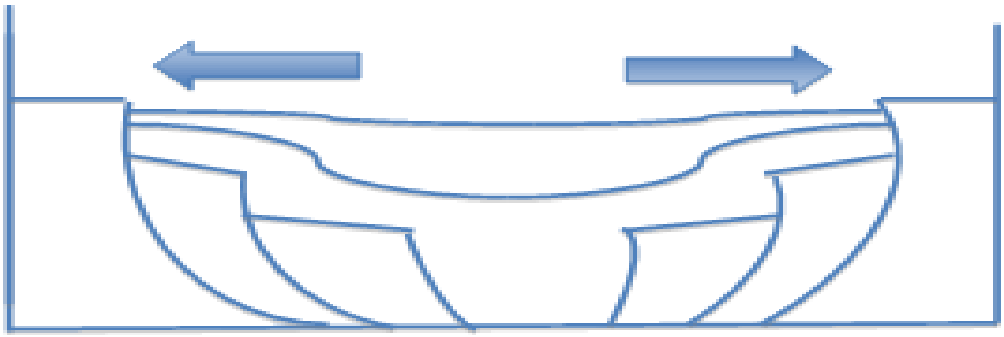


Faults are breaks in rock where one side is displaced relative to the other. Fault displacements can be on any scale from millimetres to kilometres to hundreds of kilometres. Friction along fault surfaces causes strain to build up and be released as earthquakes. Stress causing fault movement is greatest along continental plate margins. The Indo-Australian plate moves northward relative to the Eurasian plate at about 10mm per year. Earthquakes are frequent and severe. Luckily Australia lies away from the margins of its plate.

1. **Normal Fault - Extension of Crust**

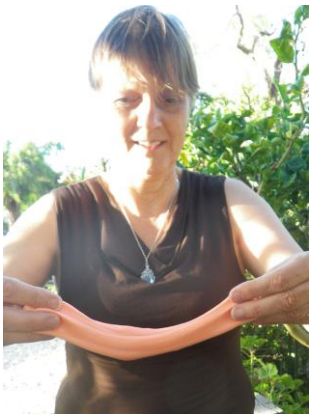
Where the crust is being stretched or extended "normal" faults occur. During ancient geological times Australia, India, Africa, New Zealand and Antarctica were welded together to form the supercontinent of Gondwanaland. About 184 million years ago the supercontinent began to break up and the present continental plates started to move apart. Continental crust between the separating plates was stretched thin and was split by a series of faults. The stretched crust then sagged to create a marine sedimentary basin bounded by fault block ranges. The diagram below is a section through the Earth.

WEST EAST



Crust sags downward in a normal fault.

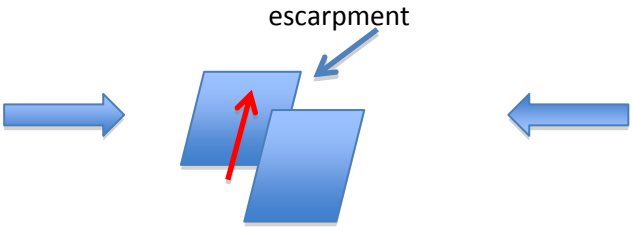
Three Types of Fault - Teacher Notes



This sag can be demonstrated by stretching some warm silly putty or play dough. The Darling Scarp, which runs north to south near the coast of Western, Australia is a normal fault, which has been activated and reactivated over more than a billion years. The down-faulted western side has more than 15km of sediments laid down in it and the Indian Ocean fills the sagging central portion.
The African Rift Valley crust is presently being stretched east to west this has resulted in north to south aligned normal faults on either side.

2. **Reverse Fault - Compression**
   Where the crust is being compacted blocks slip over and under each other. If the fault lies between 0 and 20° it can be called a thrust fault but over that it is called a reverse fault. Blocks are pushed over each other or raised upwards to form small escarpments.

Reverse fault



Meckering is a small town on the Great Eastern Highway between Northam and Cunderdin. In 1968 it was struck by a major earthquake of magnitude 6.9 in1968. Thrust faults over 17km long could be seen as ridges up to 2m tall running across farmland. The ridges have since disappeared due to weathering. Major thrust zones occur where the Australian continental plate is riding up over the Pacific plate.

3. **Transform Faults - Lateral Movement**
   Where the movement is mostly horizontal and one block slips alongside another, transform faults occur. The San Andreas Fault on the western coast of the USA is such a fault. The Pacific Plate is moving at a different speed to the North American Plate causing increasing horizontal displacement.

Normal faults result in extension of the crust E.g. Darling Fault
Reverse faults result in contraction of the crust E.g. Meckering Fault
Where the crust is being sheared and blocks move laterally, transform faults occur. E.g. San Andreas Fault and Christchurch Fault

Faults can be reactivated over millions of years with quiet periods between. Repeated extension and compressional movements are critical to understanding hydrocarbon migration potential and fault trap creation of the oil and gas fields in the North West Shelf and gold mineralisation in the Kalgoorlie Boulder area.

An initiative supported by Woodside and ESWA

Three Types of Fault - Teacher Notes

Student understanding and ability to remember different fault types can be enhanced by concrete operational activities. They will be able to see the 3D expression of faults at hand. Coloured layered polystyrene or plasticine blocks are excellent for this purpose. Polystyrene blocks are best cut and painted in layers in advance. Computer packaging often has textural layered bands already.
If the plasticine is to be separated and used again afterwards it is wise to dust the interfaces with talcum powder. Multi layer sandwiches are also excellent but must be prepared out of the science laboratory if they are to be eaten later.

Materials per student or group

- Four polystyrene blocks the same size (6cm by 5cm by 4cm is good) Polystyrene is commonly used for packing computers and other electronic equipment.
- Three different colours of PVA paint (old house paint is good)
- Brushes
- Jam jar or beaker with water for the paint brushes
- Old newspaper
- Stanley or other reasonably sharp knife. Safety rules!
- Toothpicks

Method:

1. Lay down the newspaper to protect the bench.
2. Paint three layers of different colours onto each block to represent three layers of sedimentary rock.
3. Leave to dry.
4. You have a model of four piles of sedimentary rock.

OR

Three Types of Fault - Teacher Notes

Materials per student or group

- Three lots of different coloured plasticine
- A knife
- Old newspaper

Method:

1. Lay down the newspaper to protect the bench.
2. Divide the plasticine into four and flatten it to a thick square by squeezing between thumb and forefinger.
3. Layer the plasticine to represent sedimentary rock and cut into four equal sized pieces.
4. You have a model of four piles of sedimentary rock.

We wanted to demonstrate three different fault types. Why have we got four specimens? One is the ***CONTROL*** against which any change can be measured. The others are the experimental models.

Which form of fault resulted in contraction (shortening) of the crust? Please include your primary data to support your theory. The reverse fault results in contraction of the crust. The horizontal length has decreased from _____ to _____.

Which form of fault resulted in extension of the crust? Please include your primary data to support your theory. The normal fault results in extension of the crust. The horizontal length will have increased from _____ to _____.

Which form of fault resulted in horizontal relocation of the crust? Please include your primary data to support your theory. The transform fault results in horizontal relocation of the crust. Blocks have been displaced by _____

Miners and geologists call the plane of movement "the wall". The upper side is known as the "hanging wall" because it hangs above you when you are underground. For similar reasons the lower wall is known as the "foot wall". In normal faults the hanging wall moves upwards whilst in reverse faults it moves downwards.
Faults are very important in mining as they can provide paths for mineralisation but they can also cut off and displace mineralised beds and veins.

Three Types of Fault - Teacher Notes

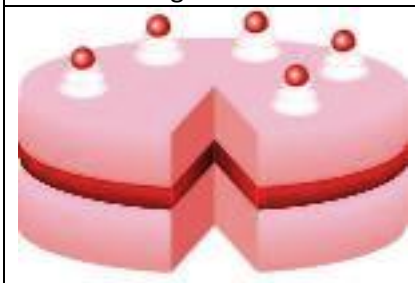
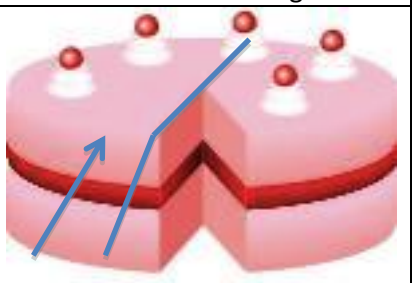
Extension - Finding fault - Use your knowledge

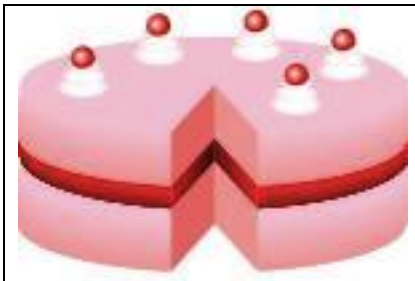
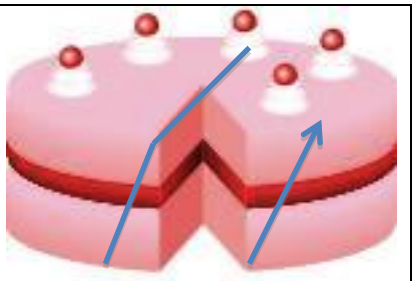
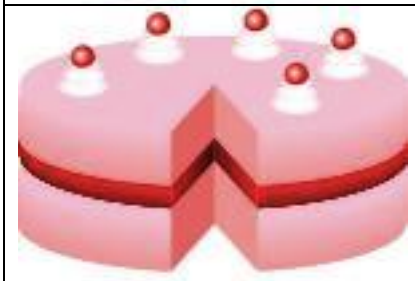
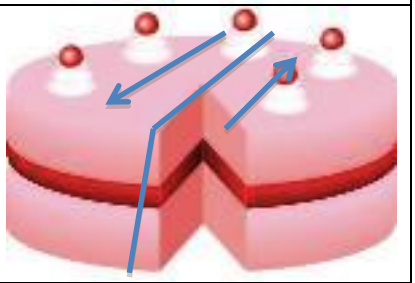
1. Meckering is a small town on the Great Eastern Highway between Northam and Cunderdin in Western Australia. Immediately after the earthquake in 1968 farmers noticed little scarps a few centimeters high running in bands across their fields. It looked like a series of steps that had been pushed up. Which kind of faults would have caused these? Explain your answer. These were reverse faults as the hanging wall block had moved upwards. The faulting was caused by compression.

2. In East Africa two major blocks of land are moving apart causing the Great Rift Valley to form between them. Every year it gets wider and wider. What kind of faults would margin this valley? Explain your answer. These are normal faults because the crust is extending and sagging between them.

3. When the Cadoux fault reactivated in 1979, farm tracks were displaced sideways and they had to be rebuilt. What kind of faults would have caused this? Explain your answer. These were transform faults as the line of the track was moved laterally.

This birthday cake is going to suffer faulting. Sketch what would happen if it was to suffer the three main types of faults we have studied.

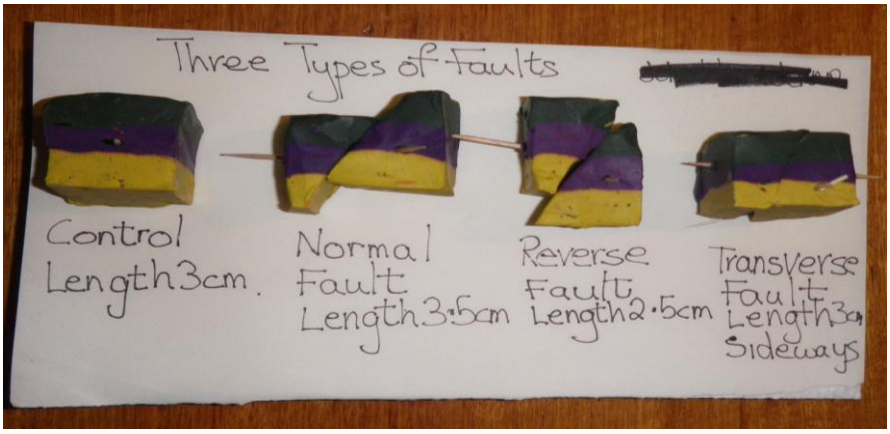
Original Cake	Type of fault	Result of faulting
	Reverse fault Compression	

	Normal fault Extension	
	Transform fault Shear	

Three Types of Fault - Teacher Notes

Almost all Australian earthquakes have a component of compression producing uplift. Compression is a major component in the earthquake swarms near Dumbleyung and Hyden.
The Darling Fault, which runs 2,000km north to south in Western Australia, has moved many times. Sometimes the western block has moved up and sometimes down. Faults are rarely single zones moving consistently in one direction.

Three dimensional fault models are good for exhibitions in the school library, entrance or at Science Fairs.



Three Types of Fault - Student Activity

Faults are breaks in rock where one side is displaced from the other. Although Australia lies well away from the stressed margins of the Australian tectonic plate many adjustments have to be made as it travels northward.

Your teacher will present you with materials to make models of the three main types of fault. Four layered blocks of the same size will be required. What is the purpose of the fourth block?

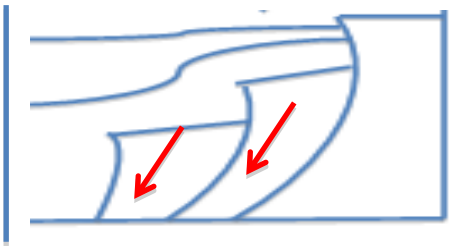
_____

Different types of faults

1. **A normal fault**

Where the crust is being stretched or extended **"normal" faults** occur. When Australia broke away from the supercontinent Gondwana, the crust was stretched and the major north to south Darling Fault was re-activated. The land to the wast slumped down to form the sedimentary basin of the Indian Ocean. Under the city of Perth the land has down faulted at least 15km. The diagram is a section down through the lithosphere.

WEST EAST



Maximum dimensions (mm)	Control block	Normal faulted block
Length		
Width		
Height		

Sketch of control and normal fault models

Control Block	Normal faulted block
Scale 1:	Scale 1:

Three Types of Fault - Student Activity

2. A reverse fault

Where the crust is being compacted (squashed together), as near Meckering on the Great Eastern Highway between Northam and Cunderdin, blocks slip up over and each other. "Reverse" faults occur. The diagram below is a section down through the lithosphere.

Maximum dimensions (mm)	Control block	Normal faulted block
Length		
Width		
Height		

Sketch of control and reverse fault models

Control Block	Normal faulted block
Scale 1:	Scale 1:

Fascinating fact: Gold bearing quartz veins can be associated with this form of faulting in our Goldfields.

3. Transform faults

Where the movement is mostly horizontal and one block slips alongside another, transverse faults occur. Movement along transform faults has caused major earthquakes in Christchurch, New Zealand. These major earthquakes happened at plate boundaries where stress is greatest.

Maximum dimensions (mm)	Control block	Normal faulted block
Length		
Width		
Height		

Three Types of Fault - Student Activity

Sketch of control and transform models

Control Block	Normal faulted block
Scale 1:	Scale 1:

Which form of fault resulted in contraction (shortening) of the crust? Please include your own primary data to support your theory.

_____

_____

Which form of fault resulted in extension of the crust? Please include your own primary data to support your theory.

_____

_____

Which form of fault resulted in horizontal relocation of the crust? Please include your own primary data to support your theory.

_____

_____

Three Types of Fault - Student Activity

EXTENSION - Finding Fault - Use Your Knowledge

1. Meckering is a small town on the Great Eastern Highway between Northam and Cunderdin in Western Australia. Immediately after the earthquake in October 1968 farmers noticed little scarps a few centimeters high running in bands across their fields. They looked like a series of steps that had been pushed up. Which kind of faults would have caused these? Explain your answer.

_____

_____

_____

2. In East Africa two major blocks of land are moving apart creating the Great Rift Valley to form between them. Every year the valley between gets wider and wider. What kind of faults would margin this valley? Explain your answer.

_____

_____

_____

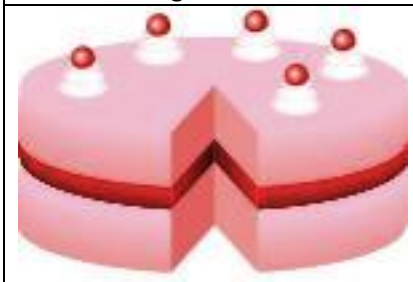
3. When the Cadoux fault reactivated in 1979, farm tracks were displaced sideways and had to be rebuilt. What kind of faults would have caused this? Explain your answer.

_____

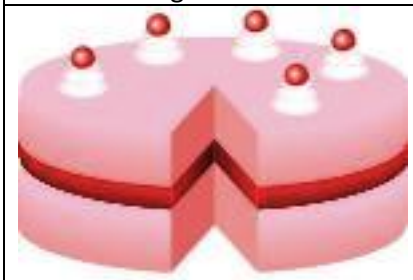
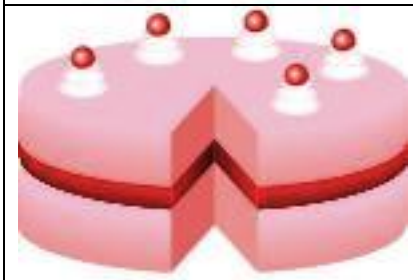
_____

_____

This birthday cake is going to suffer faulting. Sketch what would happen if it was to suffer the three main types of faults we have studied.

Original Cake	Type of fault	Result of faulting
		

Three Types of Fault - Student Activity

Original Cake	Type of fault	Result of faulting
		
		

This activity is even better with real cakes!

Fold Movement – Teacher Notes

During tectonic movement plates are stretched and compacted.

1. **Plates Moving Apart - The Continental Crust Extends and Sags**

When parts of continental crust move apart or diverge, the stretched mid section sags to form a sedimentary basin. Sediments weathered and eroded from marginal areas are deposited here. The sediments are sometimes called rift-sag deposits. Sediments are compacted and cemented to form sedimentary rock. Sedimentary rock is more plastic than igneous rock because it is not constrained by interlocking crystals.

A demonstration of sag using “silly putty” or play dough can be used but plasticine is too stiff unless seriously warm.

Recipe for play dough

- 2 cups of plain flour
- 1 cup of salt
- 2 tablespoons of cooking oil
- 4 tablespoons of cream of tartar
- 2 cups of very hot water
- Food dye

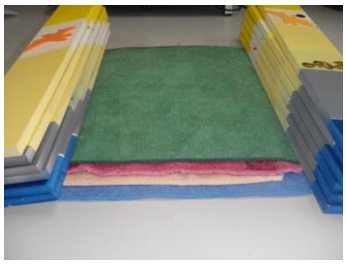
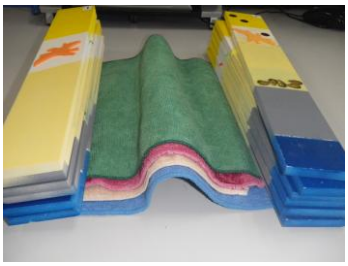
Place all in a bowl and stir.
Remove and knead to a smooth elastic ball
This recipe can be used for all fold and fault activities although at least three different colours of dough is necessary.

In Western Australia the Hamersley Basin formed between the Pilbara Craton and the Yilgarn Craton about 2.4 billion years ago. Into this depression poured the weathered and eroded volcanic rocks that make up our Banded Iron Formations (BIFs) that weathered to create our iron ore deposits.

Fold Movement – Teacher Notes

2. Plates Moving Together - The Continental Crust Crumples and Shortens

When plastic rocks move together they crumple and form folds. A demonstration of folding can be made using soft fabrics such as towels pressed together by large books.


This activity demonstrates the formation of anticlines (domes) well but does not demonstrate synclines (down warp) as the table surface restricts downward movement. Continental crust however can down warp into the underlying denser oceanic crust. Most large mountain ranges such as the Himalayas have deep 'roots". These mountains are being forced upwards by the northward movement of the continent of India.

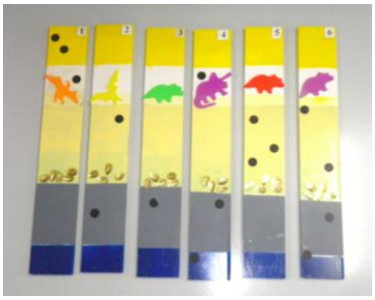
One of the major concepts in Earth Science is "The Principle of Original Horizontality". Most sediment is laid down in horizontal beds. Although in detail such materials as dune sands may have local bedding dips, over geographical distances the bedding is functionally horizontal. We assume any change from horizontality is caused by tectonic events. These are BIFs from the Hamersley Basin which were originally horizontal but have been folded by tectonic forces.

<u>AIM</u> **To model folding**

Most sediment is originally deposited as horizontal beds in sedimentary basins. Younger beds are deposited on top of older beds. Incompetent (plastic) beds will respond to pressure by folding. Hard, competent beds will fault.
Earth movements deform these into folds and faults.

MATERIALS per student

- Cardboard
- Coloured pens & pencils
- Ruler
- Option adhesive stickers to indicate fossils
- Scissors



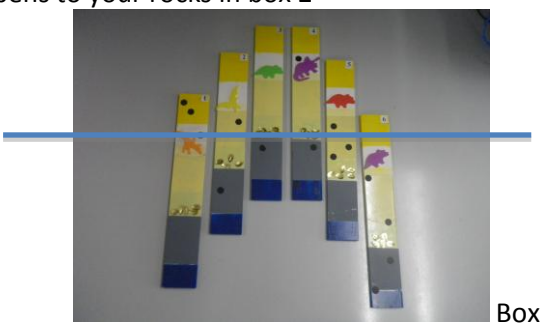
Fold Movement – Teacher Notes

Method:
1. Draw a series of horizontal beds on the cardboard and colour.
2. Add fossils either by drawing them or using stickers. Please note that fossils of the same age should be on the same bed.
3. Rule the cardboard into six vertical sections and cut to create six rock columns. These will represent drill cores cut down into the rock.

Will the oldest rock be at the top or at the bottom? At the bottom.
Sketch your rock beds in box 1 provided in the worksheet


Box 1: **Horizontal strata (control)**

Compressive forces will force your sediment to bend to form an anticline (dome)
Sketch what happens to your rocks in box 2

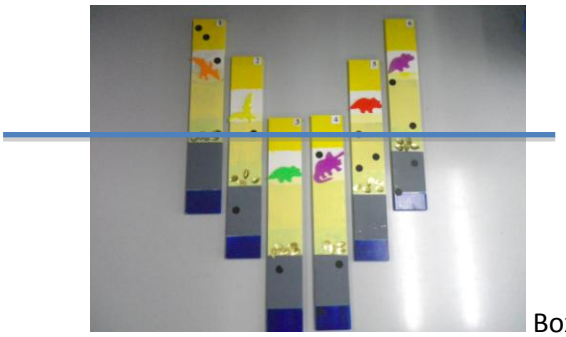

Box 2: **An anticline**

Draw a horizontal line across your rock columns to represent the eroded surface.

If erosion wears away the anticline to a horizontal surface like this one, will the oldest or youngest rocks be in the centre? The oldest rocks are at the centre of the anticline

If the rocks are compressed they may also form a syncline (be deformed into a downward curve)
Sketch what happens to your rocks in box 3

Fold Movement – Teacher Notes



Box 3: **A syncline**

Draw a horizontal line across your rock columns to represent the eroded surface.

If erosion wears away the anticline to a horizontal surface like this one, will the oldest or youngest rocks be in the centre? The youngest rocks are at the centre of the syncline

Would the mountains be folded into synclines or anticlines? Both

As a result of folding, would the length of a piece of crust be shortened or lengthened? Shortened.

As a result of folding, would the thickness of a piece of crust be increased or decreased? Increased.

The Australian continent is slowly moving northward to push up against the Asian continental plate. Would the folded mountain ranges in Papua New Guinea be the result of compression or extension? Compression

Extension

Repeat this activity with rocks whose beds dip to the left

The oldest rocks are still in the centre of the anticline and at the outer edge of the syncline. Any surface outcrops would however be asymmetric.

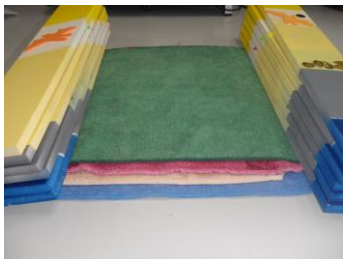
Fold Movement - Student Activity

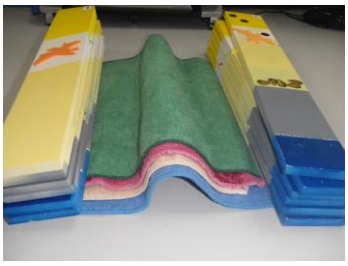
1. **Rocks Moving Apart - The Crust Extends and Sags**

When continental crust stretches during tectonic movement the mid section sags to form a ***sedimentary basin.***

Into this basin are deposited sediments eroded from the surrounding land. These sands, silts and muds are compacted by overlying layers and form sedimentary rock such as sandstone, siltstone and mudstone.

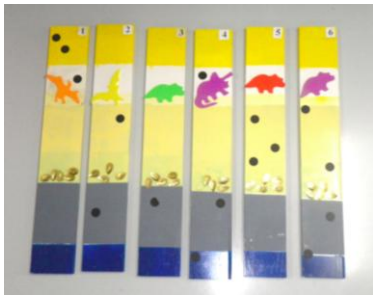
2. **Rocks Moving Together - The Crust Shortens and Folds**





Most sediment is originally deposited in horizontal beds in sedimentary basins, younger beds being deposited on top of older beds. Beds that are incompetent (plastic) will respond to pressure by folding.

<u>AIM</u> **To model folding in the continental crust**



MATERIALS per student

- Cardboard or thick paper
- Coloured pens & pencils
- Ruler
- Option adhesive stickers to indicate fossils
- Scissors

Method:

1. Draw a series of horizontal beds on the cardboard sheet and colour to represent sedimentary beds (as above). This diagram represents a vertical section cut down into sedimentary beds, like the exposure seen in a road cutting.
2. Add fossils either by drawing them or by using stickers. Please note that only fossils of the same age should be in the same bed or sedimentary layer.

Fold Movement - Student Activity

3. Rule the cardboard into six vertical sections and cut to create six rock columns. These will represent drill cores cut down into the rock.

Will the oldest rock be at the top or at the bottom?

_____

Sketch your rock beds in box 1 below

Box 1: **Horizontal strata**

Compressive forces will force your sediment to bend to form an anticline (dome)
Sketch what happens to your rocks in box 2 below

Box 2: An anticline

Fold Movement - Student Activity

Draw a horizontal line across your rock columns to represent the eroded surface.

If erosion wears away the anticline to a horizontal surface like this one, will the oldest or youngest rocks be in the centre?

_____

If the rocks are compressed they may also form a syncline (be deformed into a downward curve) Sketch your rock beds in box 3 below

Draw a horizontal line across your rock columns to represent the eroded surface.
If erosion wears away the anticline to a horizontal surface like this one, will the oldest or youngest rocks be in the centre?

_____

As a result of folding, would the length of a piece of crust be shortened or lengthened? _____

As a result of folding, would the thickness of a piece of crust be increased or decreased? _____

The Australian continent is slowly moving northward to push up against the Asian continental plate. Would the folded mountain ranges in Papua New Guinea be the result of compression or extension?

_____

Folds in the 1.6 billion year old Banded Iron Formations of our Pilbara

Folding and Faulting - Review (Teacher)

C	C	E	T	Q	F	Y	U	V	K	T	T	Z	T	C
U	O	Q	N	D	R	O	F	I	F	R	L	N	C	U
C	N	M	L	I	X	F	N	D	A	W	E	U	R	R
I	V	S	P	N	L	E	A	N	V	M	I	C	U	R
N	E	S	U	R	T	C	S	U	I	N	D	G	S	E
O	C	E	R	I	E	F	N	D	L	Y	S	Y	T	N
T	T	R	C	E	O	S	E	Y	B	T	V	F	H	T
C	I	T	G	R	V	S	S	Y	S	Z	Q	H	C	F
E	O	S	M	A	C	E	N	I	L	C	I	T	N	A
T	N	X	N	D	S	W	R	F	O	A	Y	G	N	U
M	O	V	E	M	E	N	T	S	P	N	M	I	X	Y
E	C	N	E	I	C	S	E	L	E	K	G	R	F	T
E	N	E	R	G	Y	Y	A	W	X	R	T	V	O	O
D	L	O	F	S	S	T	I	N	A	U	U	F	P	N
R	I	E	C	G	E	M	I	M	X	C	G	J	K	E

ANTICLINE
COMPRESSION
CONVECTION
CRUST
CURRENT
ENERGY
FAULT
FOLD
KINETIC
MARGIN
MOVEMENT
NORMAL
PLATE
REVERSE
SAG
SCIENCE
SEDIMENT
STRESS
SYNCLINE
TECTONIC
TRANSFORM

1. Name three types of faults Normal, reverse & transform faults
2. Which fault type causes the crust to extend or stretch? Normal faults
3. Which fault type causes the crust to compress? Reverse faults

Draw a simple diagram to demonstrate how movement in the asthenosphere can cause tectonic plates to converge and to diverge.

Folding and Faulting - Review

C	C	E	T	Q	F	Y	U	V	K	T	T	Z	T	C
U	O	Q	N	D	R	O	F	I	F	R	L	N	C	U
C	N	M	L	I	X	F	N	D	A	W	E	U	R	R
I	V	S	P	N	L	E	A	N	V	M	I	C	U	R
N	E	S	U	R	T	C	S	U	I	N	D	G	S	E
O	C	E	R	I	E	F	N	D	L	Y	S	Y	T	N
T	T	R	C	E	O	S	E	Y	B	T	V	F	H	T
C	I	T	G	R	V	S	S	Y	S	Z	Q	H	C	F
E	O	S	M	A	C	E	N	I	L	C	I	T	N	A
T	N	X	N	D	S	W	R	F	O	A	Y	G	N	U
M	O	V	E	M	E	N	T	S	P	N	M	I	X	Y
E	C	N	E	I	C	S	E	L	E	K	G	R	F	T
E	N	E	R	G	Y	Y	A	W	X	R	T	V	O	O
D	L	O	F	S	S	T	I	N	A	U	U	F	P	N
R	I	E	C	G	E	M	I	M	X	C	G	J	K	E

There are 21 words on this topic in the word sleuth above. Find them and write them below

1. Name three types of faults _____
2. Which fault type causes the crust to extend or stretch? _____
3. Which fault type causes the crust to compress? _____

Draw a simple diagram to demonstrate how movement in the asthenosphere can cause tectonic plates to converge and to diverge.

Convection Currents – Teacher Notes

Heat moves slowly through the solid parts of our Earth by conduction, the physical transfer of kinetic energy and more quickly by convection, the movement of molecules. There are two sources of heat, residual heat released during compression of cosmic dust at the time of formation of our planet and radioactive heat resulting from the spontaneous breakdown of radioactive minerals predominantly uranium, thorium and potassium.

A common misconception by students is that the Sun is the source of all energy on Earth.

A convection current is a current caused by the expansion of a liquid or gas as its temperature rises. Increased kinetic energy causes molecules to move faster and the material to expand decreasing its density. The material rises until it cools, becomes denser and descends.
At the core-mantle interface and at the mantle crust interface local zones of melting occur. Rocks melt, expand and rise through overlying layers. The Asthenosphere at the base of the crust is the source of the convection currents that are believed to power Plate Tectonics. Area where convection currents drive plates together are known as zones of convergence or destructive boundaries. Where currents bring melted material to the surface and new seafloor is formed are known as constructive zones.

Potassium permanganate is commonly known as Condy's crystals. It is a strongly oxidising and leaves permanent stains on fingers, clothes and desks. Use metal forceps or a wooden pop stick to transfer it. It might be safest for the teacher to distribute it if students perform the activity.

AIM To demonstrate a convection current

Materials per teacher or group

- Large beaker of cold water straight from the refrigerator (add ice cubes if the water is warm from the tap).
- Empty, clean, small container (baby food jar or probiotic yoghurt jar)
- Lead weights or 5c pieces to weigh down the jar
- Kettle of hot water
- Potassium permanganate
- Plastic wrap
- Small elastic band
- Two skewers

Method

1. Fill the large container with very cold water.
2. Lay two long skewers beside it.
3. If the small container is plastic add weights or 5c pieces to weigh it down

4. Drop a few pieces of potassium permanganate or food colouring into the small bottle. (Use forceps if you are using potassium permanganate as it stains skin and clothes).
5. ***Carefully*** pour hot water to completely fill the small bottle.
6. ***Carefully*** cap the bottle with plastic wrap hold in place with an elastic band.
7. Lower the bottle to the foot of the large container.
8. Using the skewers make two holes in the cap of the small container. It is easier if you hold the container in place with the blunt end of one skewer while piercing with the other.

OBSERVATION
Describe what happens when the little container's cap is holed. An annotated diagram may help.
The hot purple liquid rose to the top of the water, moved along the surface and then descended down through the water again.

DISCUSSION
Using your knowledge of Kinetic Theory, explain why this happened. (HINT "density")
The hot liquid had a higher kinetic energy than the cold water. Its molecules had more energy, took up more volume and its density decreased. Being less dense it rose. When it cooled at the surface it became denser and descended. This is a convection current.

What does the hot purple water represent in this experiment? The purple water represented molten rock rising from the asthenosphere.

What do you think would happen when the rising melted rock gets to the surface? It will cool and become solid. Being solid it can no longer flow.

What happened when the purple water reached the surface and cooled? It became denser. Being a liquid it could flow downwards.

THINK

What was the source of energy in this experiment? Sun to fossil fuels to electricity to heat

What name is given to energy that increases the rate of movement of molecules?
Kinetic energy

Why were two holes punched in the lid of the little bottle? It was to let water in and permanganate solution out.

Which material was the solvent? Water

Which material was the solute? Potassium permanganate

What is the chemical formula of potassium permanganate? $KMnO_4$

Where does the heat that powers convection currents within the Earth come from? Heat comes from two sources, residual heat from the formation of the planet and from radioactive decay.

Convection Currents – Teacher Notes

Alternative experiment
This experiment is similar but involves directly dropping crystals into hot water which permits some to dissolve while falling and the remainder to spread on rising with the convection current. The convection current is less obvious.

METHOD
Set up the equipment as before without the little bottle and boil the water.
Drop one large crystal into the water close to the edge of the beaker
Do not touch or disturb the beaker
Observe and report your observations

Students can also demonstrate their Bunsen burner skills by boiling the water themselves in their beakers.

<u>Teacher talk</u>

Potassium permanganate is a powerful oxidant and was used to control bacterial and fungal infections before antibiotics were developed. In the First World War, troops endured horrific conditions especially when fighting from trenches. They were frequently soaked to the skin and were not able to change their clothes. As a result soldiers often suffered from fungal infections in their groin (mostly Candida albicans or thrush). The exception was the Scottish troops whose kilts kept that area well aired. Women reported having their loved ones come back from the front with the relevant area stained purplish brown from potassium permanganate. Underwear had to be bleached severely before being hanged on the washing line!

Some Australian teachers still have to cope with students with impetigo or “school sores”. Two bacteria Streptococcus and Staphylococcus cause this disease. In the past teachers had to look out on a class whose heads were shaved and their stubbly skin painted purple. Aren’t antibiotics wonderful - if less colourful?

Convection Currents - Student Worksheet

Convection currents are the result of expansion of a liquid or gas as its temperature rises. Taking up a larger volume whilst having the same mass means that the substance will be less dense and rise. This is why smoke rises and a layer of hot water is found at the top of standing bathwater!

Convection currents in the partially melted asthenosphere are believed to power plate tectonics.

There are two sources of heat energy within our Earth, residual heat released during compression of cosmic dust at the time of formation of our planet and radioactive heat resulting from the spontaneous breakdown of radioactive minerals.

Materials per teacher or group

- Large beaker of cold water straight from the fridge. (Add ice cubes if using warm water from the tap).
- Empty, clean, small container
- Lead weights or 5c pieces to weigh down the jar (if it is plastic)
- Kettle of hot water (CARE!)
- Potassium permanganate or food dye
- Plastic wrap and scissors
- Small elastic band
- Two skewers

Method

1. Fill the large container with very cold water.
2. Lay two long skewers beside it
3. If the small container is plastic add materials suggested by your teacher to give it negative buoyancy.
4. Drop a few pieces of potassium permanganate or food colouring into the bottle. Use forceps if you are using potassium permanganate as it stains.
5. ***Carefully*** pour hot water to completely fill the bottle
6. ***Carefully*** cap the bottle with plastic wrap and hold in place with an elastic band
7. Lower the bottle to the foot of the large container
8. Using the skewers make two holes in the cap of the small container

OPTION: Small polystyrene "continents" can be placed on the water to demonstrate movement due to rising convection currents.

Observations

Describe what happens when the little container's cap is holed. An annotated diagram may help (see next page).

Convection Currents - Student Worksheet

_____

_____

_____

_____

_____

_____

Using your knowledge of Kinetic Theory, explain why this happened. (HINT "density")

_____

_____

_____

_____

What does the hot purple water represent in this experiment?

_____

What do you think would happen when the rising melted rock gets to the surface?

_____

What happened when the purple water reached the surface and cooled?

_____

THINK

What was the source of energy in this experiment?

_____

What name is given to energy that increases the rate of movement of molecules?

_____

Convection Currents - Student Worksheet

Why were two holes punched in the lid of the little bottle?

_____

Which material was the solvent? _____

Which material was the solute? _____

What is the chemical formula of potassium permanganate? _____

Where does the heat that powers convection currents within the Earth come from? _____

_____

Problems with this theory:

1. **Classic convection cells have not yet been found in either the asthenosphere or mantle. Ongoing fluid flow does not appear to have happened in the last 2 billion years.**

2. **Mid oceanic ridges are not fixed and static but appear to have moved over geological time. The mid-Atlantic ridge is a case in point.**

3. **At subduction zones slabs sink faster than they converge suggesting gravity as the driving force at this location.**

4. **Almost 90% of our volcanoes occur in "arcs" where oceanic plate is drawn under continental crust. The volcanic material formed can be silica rich, like continental crust not iron and magnesium rich like melted oceanic crust.**

"Science changes its thinking as new ideas come along" Tim Minchin

"Nature and development of science

. *Scientific understanding, including models and theories, are contestable and are refined over time through a process of review by the scientific community (ACSHE157)*

. *Advances in scientific understanding often rely on developments in technology and technological advances are often linked to scientific discoveries (ACSHE158)*

" ACARA Australian Curriculum v5.2"

Current thinking = Slab pull

As oceanic plates move apart at mid-oceanic ridges their mafic volcanic rocks cool and become denser. The further they are away from the ridge the cooler and denser they become. Gravity causes this basalt rich crust to sag into the underlying lithosphere. This tension on either side of the ridge maintains the central trench.

Fresh basalts from the ridge flow down into the oceanic basin causing the oceanic plate to thicken. Basin sediments can also build up above them to a depth of about 5km.

Increasing gravitational force pulling on the older, colder and denser oceanic crust creates a bend or "hinge zone" in the oceanic slab and it is down warped at some distance away from the ridge. The down warped part pulls on newer portions of the oceanic crust behind it.

At a zone of convergence the down warped slab will travel below less dense younger oceanic plate or less dense continental plate and rapidly travel on down into the hotter mantle. An oceanic trench forms above it. As the slab slides down, melted sediments and out gassed water will rise through the overlying crust to produce explosive silica rich volcanic outpourings. Farther under the overlying slab, partial melting may produce more mafic intrusions and outpourings.

A rapidly downward moving slab will stretch, thin and rotate the continental crust margin. This slab pull explains passive volcanic outflows in back arc basins well behind the continental margin.

Research geologists at the University of Western Australia are computer modeling what might happen when different types of crust are subducted and partially melted. Their research informs present mineral exploration. (*Non-linear thermo mechanics of folding in geomaterials*, Paesold, M. K., Regenaur-Lieb, K., Bassom, A.P., Ord. A., Hobbs, B.E. 2013)

Current thinking leans towards the concept that heating produces expansion which is a minor force in tectonic movement. Slab pull is the major driving force.

Relating Earthquakes and Volcanic Activity to Plate Boundaries

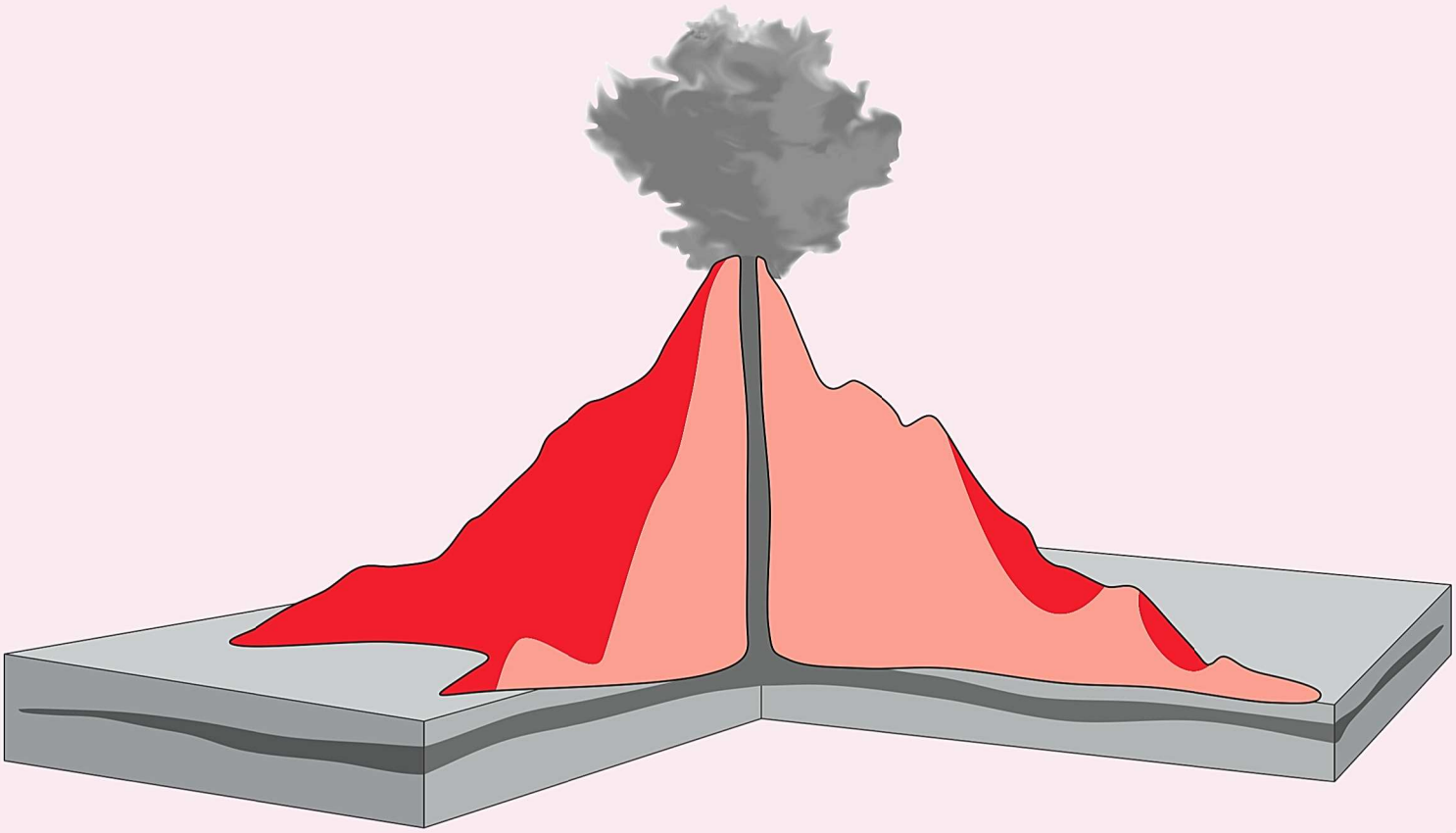


Plate Boundaries - Teacher Background

Convection currents activities provide background for this. Similarly "Folding and Faulting" provide background for how competent (rigid) rocks will break or fault while incompetent (plastic) rocks will bend or fold when stressed tectonically.
Students may wish to visit www.youtube.com/watch?v=GyMLlLxbfa4&feature=related to remind themselves about seafloor spreading and subduction zones.

There are three types of plate boundaries

1. Divergent Boundaries
2. Convergent Boundaries
3. Transform Boundaries

An animation of these three boundaries can be found at:
http://www.learner.org/interactives/dynamicearth/plate.html

1 Divergent (constructive) boundary

Oceanic crust moving apart from oceanic crust

It is thought that where two convection currents rise and cool, seafloor spreading occurs. Hot molten mafic (rich in iron and magnesium) oceanic crust rises and flows outwards from the trench in the mid oceanic ridge.

This can be described as a constructive boundary as the width of the oceanic plate is being increased. It can be likened to a conveyor belt carrying hot rock upwards and pushing earlier flows aside. Of course no new material is created, only older material brought down from elsewhere or brought up from below (Law of Conservation of Mass). Since this magma is mafic and flows easily, low shield volcanoes will form. Spreading movement is not uniform and massive transform (see below) faulting occurs. This process results in submarine earthquakes.

The classic example of a divergent or constructive boundary is the Mid Atlantic Ridge where a band of active undersea and above sea level volcanoes is presently creating fresh mafic extrusive sea floor rocks. Here the seafloor is spreading at a rate of between 2 and 6cm per year.

Evidence for seafloor spreading is found in the increasing age of rocks away from the ridge, the mirrored magnetic banding of these rocks, the relative youth of these rocks compared with continental crust and laser measurement by satellites.

Continental crust moving apart from continental crust

These boundaries are created where a continent is being split apart. A massive fault bounded rift valley forms. With associated volcanism and earthquakes. The Great Rift Valley of eastern Africa is presently being extended as Arabia is moving apart from Africa. Closer to home a zone of divergence formed when the Australian Continental Plate split apart from the Antarctic Continental Plate and is still extending.

Activities and information on divergent boundaries are described under "Evidence for Seafloor Spreading".

2 Convergent (destructive) boundary

What happens when two convection cells converge at the surface depends on the nature of the plates coming together. Where plates have the same densities they will crumple and form mountains. Where the rocks are of different densities, the denser rock will slip under the less dense crust.

Continental crust converges with continental crust

E.g. Indian plate converging with Eurasian Plate north of India
Less dense incompetent silica rich sediments from the two continental crusts crumple into each other to form high mountains such as the Himalayas. This piling of crust upon crust will cause the continent to thicken increasing pressure and temperature at the base of continental crust resulting in regional metamorphism.

This can be demonstrated by pushing two dishtowels together.

Continental crust converges with oceanic crust

E.g. Australian and Pacific plates to the north east of Australia
The denser oceanic plate will be subducted (it will slip below) the lighter continental crust. This is indicated by a zone of deepening earthquake centers moving away from the convergence overlain by high fold mountains. Often a deep trench forms over the subduction zone and major earthquakes which lift the surface metres at a time. Sediments included in the subducted plate will melt and rise to the surface as explosive silica rich volcanics forming the classic stratovolcano shape. Rock through which the volcanic magma penetrates will suffer contact metamorphism.

This can be modelled by pushing a book (dense oceanic crust) and a dish towel (less dense continental crust) together. The towel will fold over the book.

Oceanic crust with oceanic crust

E.g. the Solomon Islands and trench to the east of Australia
Whichever plate is densest will be subducted (pulled under the other plate) forming a deep oceanic trench above the subduction zone. Since this occurs away from continental crust, any volcanism will be undersea. In time these volcanoes will build up to form island arcs

3 Transform boundaries

These movements occur near the surface where cold hard rocks are required to move against each other.
This can be modelled by a student attempting to push one rock against another, or by pushing two blocks covered with sandpaper against each other. Energy is stored until limiting friction is overcome and one block moves rapidly against another.
Along major zones of movement stress builds up and one major zone of movement/fault is broken into many minor transverse faults. Transform faults are brittle and cause minor earthquakes. Stress within the continental plate is relieved by the occurrence of transform faults and earthquakes.

Continental crust is thicker (30-50 km) and less dense than oceanic crust (5-10km). It is particularly thick under mountain ranges where a "keel" sinks in the same way as an iceberg needs a keel to float in water. Rocks of the oceanic crust are continuously being recycled as they crystallise at mid ocean ridges and are melted at subduction zones. This explains why our oldest oceanic rock is a mere 200 million years old whilst continental crust rocks can date back to 3.8 billion years ago. Our knowledge of oceanic crust comes from places such as Macquarie Island and Central Tasmania where slabs of oceanic crust were thrust up onto the eastern margins of the supercontinent of Gondwana because of tectonic convergence long ago. We call these rocks ophiolites.

At destructive (convergent) boundaries crust is subducted (pushed below and melted).
At constructive (divergent) boundaries new crust is formed.
At transform boundaries crust is crumpled and broken but not subducted.
Molten continental crust is felsic (rich in silica) and does not flow easily.
Molten oceanic crust is mafic (rich in iron and magnesium) and flows easily.

Three teacher demonstrations should help explain how movement of crustal plates can cause different degrees of volcanism and earthquakes.

Movement of Crust of Different Densities - Teacher Demonstration 1

Materials

- Two gas jars, large test tubes or glasses the same size
- Sufficient oil coloured red to completely fill one gas jar
- Sufficient water coloured blue to completely fill the other gas jar
- A thin hard square of cardboard larger than the mouth of the gas jars

Method

1. Slide the cardboard over the mouth of the water filled gas jar ensuring that no air is present. The cardboard should slice off the water's meniscus.
2. Invert this jar holding the cardboard in place. Water should remain in the jar unless any air was left trapped inside.
3. Place the inverted blue water jar directly on top of the red oil filled jar.
4. Remove the cardboard.
5. Denser water (1g/cm^3) should move down into the lower jar to replace the rising oil (0.9g/cm^3).

We know that oceanic crust is denser, younger and thicker than continental crust and underlies it.

Which is denser, oil or water? Explain your answer.
Oil is less dense than water because it floated above water.

From what happened in this experiment i***nfer*** what would happen if oceanic crust converged (was pushed together) against continental crust.
The denser oceanic crust will slip below the less dense continental crust

What is meant by "***an inference***"?
A judgement given from the evidence provided

Sketch with labels what this would look like in the left section below.

Sketch 1	Sketch 2

Varying Thickness of Continental Crust - Teacher Demonstration 2

Where continental crust has been pushed together and crumpled up to create mountains a similar thickness has to be emplaced below to ensure isostacy. Isostacy is the state of gravitational equilibrium between the lithosphere and the asthenosphere.

Materials

- 1L water poured into a milk carton and frozen to create a large ice cube/rectangular prism. This is an ideal size for all the class to get a good look however a smaller container can also be used.
- 1L water poured into a plastic bag and allowed to freeze like a flat pancake.
- A pneumatic trough or other large container of water

Method

1. Place both pieces in water and allow ice to float. Observe any differences

Both pieces of ice have the same volume. Is there any difference in how they float in the liquid?
Yes. The thicker the ice sheet, the greater depth lies below water level.

What information did you gain from this activity?
Where continental crust converges with oceanic crust the oceanic crust slides below. The continental crust is crumpled and thickened both above and below sea level.

Use this information to create Sketch 2. This will improve upon your first sketch.

Interesting facts: During the last Ice Age the weight of ice on some continents depressed the crust down into the top of the asthenosphere. When the ice melted these continents very slowly started rising to regain isostacy. This has created raised fossil beach lines round the coast as the land slowly rose above sea level.

Of course weathering and erosion is extremely slowly removing rock and soil from mountains thereby resulting in an equally slow rise. The rate of erosion and transport however exceed the rate of isostatic rise!

Science changes its ideas as new information becomes available.

As more knowledge is acquired we adjust our ideas as to how things work. Science is not dogma. When we test our ideas we can gain new understanding. Fill in new ways of thinking in the table below.

Observation	Belief in Roman times	Belief in medieval times	Belief in modern times
The student is not learning	Beat his slave	Beat the student	Counsel them to better learning habits
The patient does not look well	Sweat out the disease	Bleed the patient	Find out which disease and treat scientifically
The volcano is erupting!	We have offended the gods	We have offended God	Molten magma is erupting because of tectonic pressure
This person is filthy.	Make them sweat, scrape off the sweat and rub with oil	Bath once a year whether you need it or not	Unhealthy! Go away, get some soap and water and bathe daily

Crust Chemistry and Viscosity

Viscosity is a measure of a substance's ability to flow (reduce tensile stress between moving particles). Unsaturated margarine or grease is highly viscous, tomato sauce is less viscous and water has very low viscosity. Variable viscosity can be demonstrated through swirling different liquids in a glass or a beaker.
Margarine will hardly change shape, tomato sauce will coat the base of the glass and water will splash all around the inside of the glass.

When crust is subducted it is subjected to increasing temperature and pressure. Eventually the crust will melt and form magma. The behaviour of that magma will depend on its physical and chemical characteristics. Silica poor magmas flow more easily than silica rich magmas. A volcano erupting silica rich (felsic) magma such as rhyolite will be more explosive than a silica poor (mafic) magma such as basalt.

Viscosity of Different Liquids and Magmas - Teacher Demonstration 3

Materials

- Two Pasteur or transfer pipettes
- Some tomato sauce and some water
- Glass plate or china plate
- Double folded newspaper

Method

1. Part fill one pipette with water and the other with tomato sauce.
2. Squeeze equal volumes of each onto the glass or plate and observe the shapes formed.

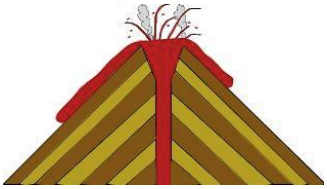
Tomato sauce represents felsic or silica rich magma made from continental crust that has been subducted and melted under great temperature and pressure. Oil represents mafic or silica poor oceanic crust that has been subducted and melted under great temperature and pressure

Science Of Plates - Teacher Notes

Describe the tomato sauce drop
Tomato sauce forms a cone or classic stratovolcano shape

Describe the water drop
Water flows to form a flatter sightly domed blob. This is the classic shield volcano shape. It is named after a warriors shield laid on its face.

Would this volcano be the result of magma from melted oceanic or continental crust? Explain your answer.
This would result from melted continental crust, as this is rich in silica giving it a high viscosity.



Refill both pipettes and quickly eject their contents over the sheet of newspaper. Note distance covered and pattern of spray.

Option
Half fill the pipettes, hold the pointing upwards and give them a good shake to include gas (air) into the mix and repeat the last experiment. Gas increases the explosive nature of extruded tomato sauce.

Which magma (molten rock) will produce the most destructive volcanic extrusions?
The tomato sauce/felsic lava splutters explosively and travels farthest. Felsic magma will produce the most destructive events. Felsic volcanoes produce sticky lava, explosions, cinder cones and ash falls.

In your second sketch add a volcano above where the crust was subducted (drawn down). The silica rich continental crust has been melted to produce silica rich (felsic) lava. What shape would your volcano be?
Cone shaped stratovolcano. This would be the result of sticky felsic magma erupting violently.

If iron and magnesium rich oceanic crust had been melted and erupted, what shape would that volcano have been?
A flatter shield like volcano because the magma has low viscosity and flows easily.

What have these experiments to do with converging plate boundaries?
If plate boundaries come together (converge) then the type of volcanism produced will relate to the chemistry/mineralogy/materials of the subducted plate. Melted continental plate will produce explosive volcanic events whilst melted oceanic plate will produce more gentle flows.
If plates diverge undersea lavas will be silica poor and flow evenly.

Science of Plates - Student Worksheet

Three teacher demonstrations should help explain how movement of crustal plates can cause different degrees of volcanism and earthquakes.

1. Movement of Crust of Different Densities

We know:
Oceanic crust is denser, younger and thinner than continental crust.

Teacher Demonstration - **Density separation of materials**

Observe the demonstration

Which is denser, oil or water? Explain your answer.

_____

_____

_____

From what happened in this experiment infer what would happen if oceanic crust converged (was pushed together) with continental crust.

_____

_____

_____

What is meant by "**an inference**"? _____

_____

Sketch with labels what this would look like in the left section below.

Oceanic crust subducted by continental crust	Continental crust converging with continental crust
Sketch 1	Sketch 2

2. Varying Thickness of Continental Crust

We know that when continental plates converge, crust is pushed together, crumpled and forms mountains.
Observe the teacher's demonstration. Ice represents crust and water represents the underlying asthenosphere.

Both pieces of ice have the same volume. Is there any difference in how different shapes float in the liquid? Describe any difference.

_____

_____

What information did you gain from this activity that would relate to continental crust "floating" on oceanic crust?

_____

_____

Use this information to create Sketch 2. This will improve upon your first sketch.
The concept of a "keel" underlying mountains is also supported by gravity surveys.

Interesting facts
During the period of the last Ice Age the weight of ice on some continents depressed the crust down into the top of the asthenosphere. When the ice melted these continents very slowly started rising (to regain isostacy). This has created raised fossil beach lines round the coast as the land slowly rose above sea level.
Of course weathering and erosion is extremely slowly removing rock and soil from mountains thereby resulting in an equally slow rise. The rate of erosion and transport however exceed the rate of isostatic rise!

Science changes its ideas as new information becomes available.

As more knowledge is acquired we adjust our ideas as to how things work. Science is not dogma. When we test ideas our ideas we can gain new understanding. Fill in new ways of thinking in the table below.

Observation	Belief in Roman times	Belief in medieval times	Belief in modern times
The student is not learning	Beat his slave	Beat the student	
The patient does not look well	Sweat out the disease	Bleed the patient	

Observation	Belief in Roman times	Belief in medieval times	Belief in modern times
The volcano is erupting!	We have offended the gods	We have offended God	
This person is filthy.	Make them sweat, scrape off the sweat and rub with oil	Bath once a year whether you need it or not	

3. Crust Chemistry and Viscosity

Viscosity is a measure of a substance's ability to flow. When crust is subducted it is subjected to increasing temperature and pressure. Crust will melt and form magma. The behaviour of that magma will depend on its physical and chemical characteristics. Silica poor magmas flow more easily than silica rich magmas. A volcano erupting silica rich (felsic) magma such as rhyolite will be more explosive than a silica poor (mafic) magma such as basalt.

Tomato sauce represents felsic or silica rich magma made from continental crust that has been subducted and melted under great temperature and pressure. Oil represents mafic or silica poor oceanic crust that has been subducted and melted under great temperature and pressure

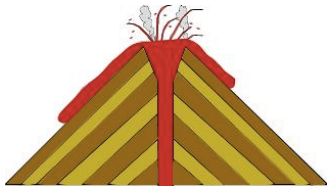
Describe the shape of the tomato sauce drop _____

_____

Describe the shape of the water (lower viscosity) drop _____

_____

Would this volcano (pictured right) be the result of magma from melted oceanic or continental crust? Explain your answer.



_____

_____

_____

Which magma (molten rock) will produce the most destructive volcanic extrusions?

_____

In your first sketch add a volcano above where the crust was subducted (drawn down). The silica rich continental crust has been melted to produce silica rich (felsic) lava. What shape would your volcano be?

_____

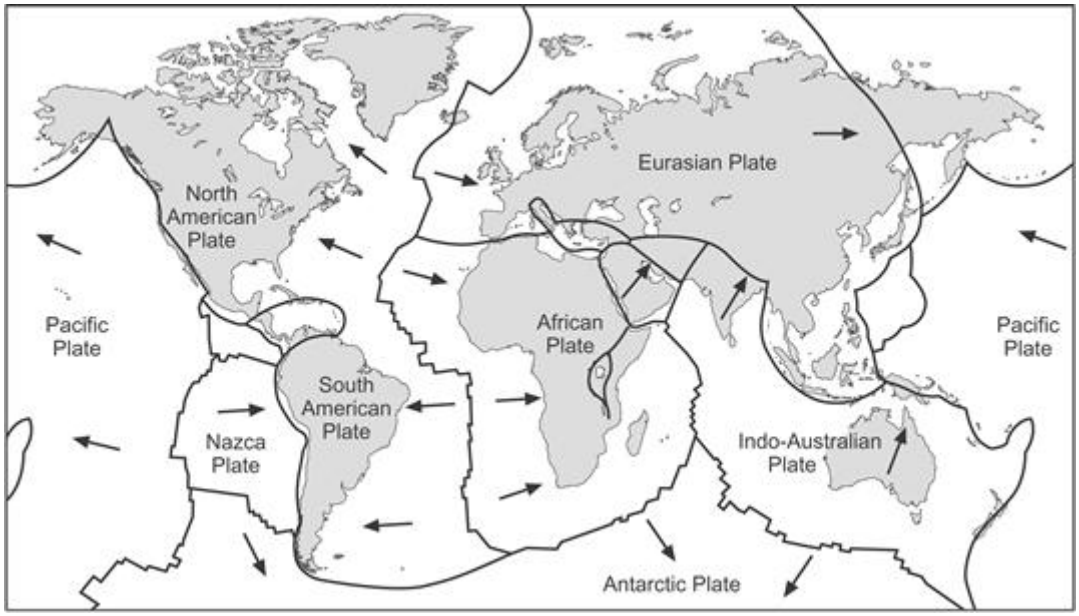
If iron and magnesium rich oceanic crust had been melted and erupted, what shape would that volcano have been?

_____

What have these experiments to do with converging plate boundaries? _____

_____

Plate Boundaries - Teacher Notes



List the eight major plates shown on the map above

1. Indo-Australian Plate
2. Antarctic Plate
3. African Plate
4. Pacific Plate
5. Eurasian Plate
6. North American Plate
7. South American Plate
8. Nazca Plate

There are many minor plates.
Does Australia sit at the edge of a continental plate? No

Does the location of Australia mean it will be unaffected by plate tectonic movements?
NO. It will not be affected as much as places like San Francisco that sits on the margins of two moving plates and consequently suffers severe earthquakes or like the Pacific Ring of Fire that suffers frequent volcanic activity. However major earthquakes at the margin of our plate and elsewhere will eventually reach Australia but their effect will be diminished. Stress created by movement at the margin of our plate is also accommodated by minor earthquakes within the plate.

Convergent, or Destructive, Plate Boundaries

Convergent boundaries are called “destructive boundaries” as crust length is shortened

Using the information gained from the previous experiments on viscosity and density, suggest what might happen when:

A. A continental plate converges with an oceanic plate, for example where the oceanic Nazca Plate is moving west towards the South American Plate. (See diagram above)

The denser Nazca Plate is subducted/pushed under the lighter South American Plate. Where it turns

to slip below the continental plate a deep oceanic trench is created. Movement along the subduction zone causes frequent earthquakes. Melted oceanic plate and pieces of asthenosphere rise to form the explosive volcanoes of the Andes Mountains.

B. Two continental plates converge, for example where the Indian Plate is converging with the Eurasian Plate

Since both plates have the same density when they collide they form high folded sedimentary mountain chains. In this case the Himalaya Mountains are raised and crumpled. Although earthquakes are produced there is no volcanic activity as there is no subduction.

These explanations are a little simplistic as although oceanic crust is dense, a thin layer of continental material that will be subducted with it always overlies it. The varying proportions of each will produce different results. Water and gases from melted continental material will also affect the final style of volcanism.

C. Older denser oceanic crust converges with younger less dense oceanic crust, for example where older Australian Plate meets the younger New Zealand Plate

Violent earthquakes and volcanism occurs. E.g. Indonesian Island Arc and New Zealand where the Pacific and Australian plates are colliding

Using the map above name three convergent plate boundaries. _____

Divergent Boundaries

Constructive boundaries, also known as ***divergent boundaries***, occur where two plates move apart. They are called constructive because seafloor spreading extends the crust.

Teacher Demonstration - Stretching the crust

Materials

- Silly putty or play dough
- Teacher or student

Warm putty in hands and roll into a thick sausage shape.
Stretch the sausage gently between two hands.
The putty should thin and sag towards the centre.

Tension thins the crust, and normal faulting produces a rift valley. Molten mafic material from oceanic crust and the mantle rises to form mid-oceanic ridges and flat basalt plains. Mafic volcanic rocks are free flowing therefore earthquakes and volcanic activity is not very destructive.

E.g. Mid-Atlantic Ridge where the North American Plate moves away from the Eurasian Plate.

Plate Boundaries - Teacher Notes

Using the map name three divergent plate boundaries. _____

Where are most divergent boundaries found? Mid-oceanic ridges

Transform Boundaries

These occur when two plates scrape past each other. There is no volcanic activity but strong earthquakes occur. E.g. San Andreas Fault where friction between the Pacific Plate and North American Plate builds up to be released in a series of earthquakes.

Animations of these three boundaries can be found at:
http://adjr06.tripod.com/id8.html

Summary

Complete the following summary statements.

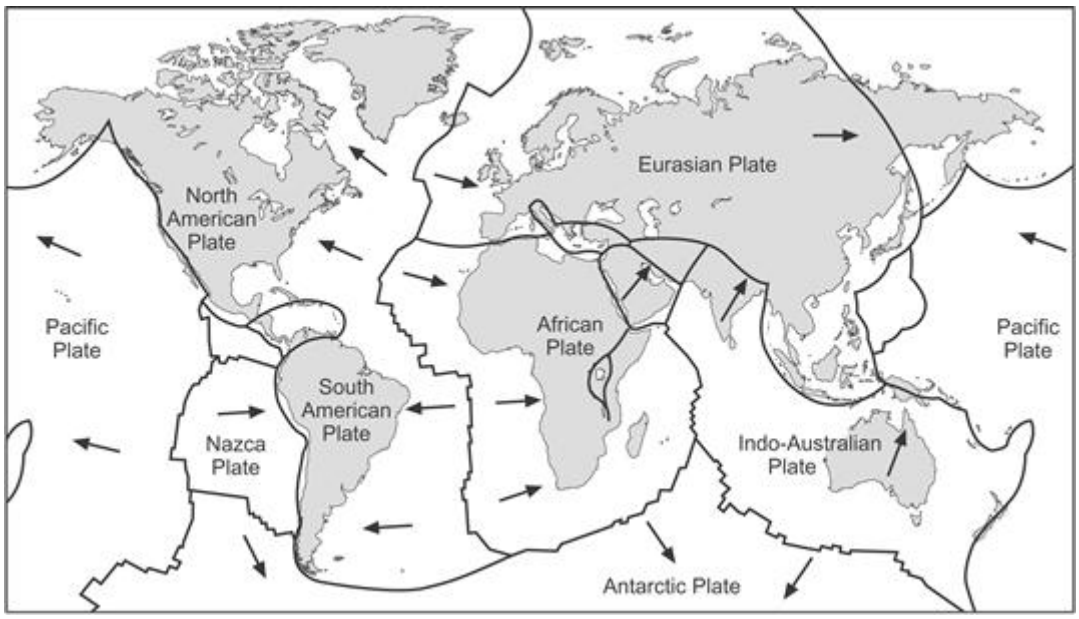
At destructive (convergent) boundaries crust is subducted (pushed below and melted).
At constructive (divergent) boundaries new crust is created.
At transform boundaries crust is crumpled and broken but not subducted.
Molten continental crust is felsic (rich in silica) and magma does not flow easily.
Molten oceanic crust is mafic (rich in iron and magnesium) and flows easily.

Extension Activity

Students may wish to replicate movement at plate boundaries by:

1. Making their own stop – go animations using cameras and plasticine/clay.
2. Drawing cartoons or posters explaining the different types of movement and the results of their movement.
3. Dramatic performances with students taking on the parts of plates and observers.
4. Using Google satellite imaging to locate major active plate margins.

Plate Boundaries - Student Activity



List the eight major plates shown on the map above

_____

_____

_____

There are many minor plates.

Does Australia sit at the edge of a continental plate? _____

Does the location of Australia mean it will be unaffected by plate tectonic movements? Explain your answer.

_____

_____

_____

Convergent, or Destructive, Plate Boundaries

Convergent boundaries are called "destructive boundaries" as crust length is shortened
Using the information gained from the previous experiments on viscosity and density, suggest what might happen when:

A. A continental plate converges with an oceanic plate, for example where the oceanic Nazca Plate is moving west towards the South American Plate. (See diagram above)

_____

_____

B. Two continental plates converge, for example where the Indian Plate is converging with the Eurasian Plate

_____

_____

_____

C. Older denser oceanic crust converges with younger less dense oceanic crust, for example where older Australian Plate meets the younger New Zealand Plate

_____

_____

_____

Using the map name three convergent plate boundaries.

_____

_____

Divergent Boundaries

Constructive boundaries, also known as ***divergent boundaries***, occur where two plates move apart. They are called constructive because sea floor spreading extends the crust.

Teacher Demonstration - Stretching the Crust

Tension thins the crust, and normal faulting produces a rift valley. Molten mafic material from oceanic crust and the mantle rises to form mid-oceanic ridges and flat basalt plains. Mafic volcanic rocks are free flowing therefore earthquakes and volcanic activity is not very destructive.

E.g. Mid-Atlantic Ridge where the North American Plate moves away from the Eurasian Plate.

Using the map name three divergent plate boundaries. _____

_____

Plate Boundaries - Student Activity

Where are most divergent boundaries found? _____

Transform Boundaries

These occur when two plates scrape past each other. There is no volcanic activity but strong earthquakes occur. Friction builds up to be released in a series of earthquakes.

Using the map name a transform plate boundary _____

Animations of these three boundaries can be found at:
http://adjr06.tripod.com/id8.html

Summary
Complete the following summary statements.

At destructive (convergent) boundaries crust is _____

_____

At constructive (divergent) boundaries _____

_____

At transform boundaries crust is _____

_____

Molten continental crust is _____

_____

Molten oceanic crust is _____

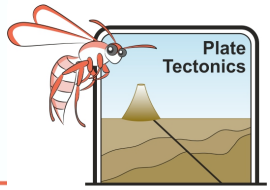
_____

Extension Activity

Students may wish to replicate movement at plate boundaries by:

1. Making their own stop – go animations using cameras and plasticine/clay.
2. Drawing cartoons or posters explaining the different types of movement and the results of their movement.
3. Dramatic performances with students taking on the parts of plates and observers.
4. Using Google satellite imaging to locate major active plate margins.

Plate Boundaries – Review (Teacher)



I	C	O	N	V	E	R	G	E	N	T	E	G	S	L
D	N	S	E	A	Y	M	V	I	L	V	U	N	T	A
I	H	D	N	A	O	R	S	O	I	A	O	D	R	T
V	E	D	O	L	R	O	T	T	L	R	V	T	A	N
E	L	V	T	A	S	T	C	S	T	C	R	A	T	E
R	C	E	I	T	U	U	H	H	I	A	A	R	O	N
G	N	I	A	T	R	S	A	Q	N	M	E	N	V	I
E	E	C	N	T	C	M	T	S	U	L	E	A	O	T
N	Y	T	S	A	E	U	F	R	C	A	K	H	L	N
T	T	E	S	R	E	O	R	Y	A	Z	K	P	C	O
O	D	V	I	U	R	C	C	T	A	L	G	E	A	C
F	U	C	Y	M	R	E	O	N	S	L	I	A	N	J
M	A	N	T	A	R	C	T	I	C	N	F	A	O	U
N	A	C	I	R	E	M	A	H	T	U	O	S	N	X
Y	T	I	S	O	C	S	I	V	J	H	Q	C	H	U

ANTARCTIC
CHEMISTRY
CONSTRUCTIVE
CONTINENTAL
CONVERGENT
CRUST
DESTRUCTIVE
DIVERGENT
EARTHQUAKE
INDOAUSTRALIAN
ISOSTACY
LAVA
MOLTEN
NAZKA
NORTHAMERICAN
OCEANIC
RECYCLE
SOUTHAMERICAN
STRATOVOLCANO
TRANSFORM
VISCOSITY
VOLCANO

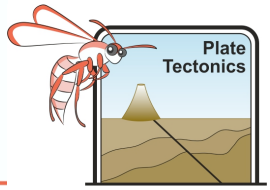
1. **At destructive (convergent) boundaries crust is subducted (pushed below and melted).**

2. **At constructive (divergent) boundaries new crust is created.**

3. **At transform boundaries crust is crumpled and broken but not subducted.**

4. **Do volcanoes from molten oceanic crust have lava which flows more easily or less easily than those which have molten continental crust? more easily**

Plate Boundaries – Review (Student)



I	C	O	N	V	E	R	G	E	N	T	E	G	S	L
D	N	S	E	A	Y	M	V	I	L	V	U	N	T	A
I	H	D	N	A	O	R	S	O	I	A	O	D	R	T
V	E	D	O	L	R	O	T	T	L	R	V	T	A	N
E	L	V	T	A	S	T	C	S	T	C	R	A	T	E
R	C	E	I	T	U	U	H	H	I	A	A	R	O	N
G	N	I	A	T	R	S	A	Q	N	M	E	N	V	I
E	E	C	N	T	C	M	T	S	U	L	E	A	O	T
N	Y	T	S	A	E	U	F	R	C	A	K	H	L	N
T	T	E	S	R	E	O	R	Y	A	Z	K	P	C	O
O	D	V	I	U	R	C	C	T	A	L	G	E	A	C
F	U	C	Y	M	R	E	O	N	S	L	I	A	N	J
M	A	N	T	A	R	C	T	I	C	N	F	A	O	U
N	A	C	I	R	E	M	A	H	T	U	O	S	N	X
Y	T	I	S	O	C	S	I	V	J	H	Q	C	H	U

There are 22 words about earthquakes and plate boundaries above. Write them below.

1. At destructive (convergent) boundaries crust is _____

   _____

2. At constructive (divergent) boundaries crust is _____

   _____

3. At transform boundaries crust is _____

   _____

4. Do volcanoes from molten oceanic crust have lava which flows more easily or less easily than those which have molten continental crust?

   _____

   _____

Since Australia and its continental shelf lie well within the greater Australian Continental Plate we do not suffer from the major quakes felt on continental plate margins where the crust may be crumpled upwards, subducted downwards or sheared against another continental plate.

Our knowledge of faults causing earthquakes is limited by:

- Geological knowledge. Some resource rich areas have been mapped in minute detail whilst less explored areas are mapped in less detail. (Funds from the "Royalties for Regions" program are being expended in geological and geophysical exploration of promising oil, gas and mineral rich provinces in Western Australia).

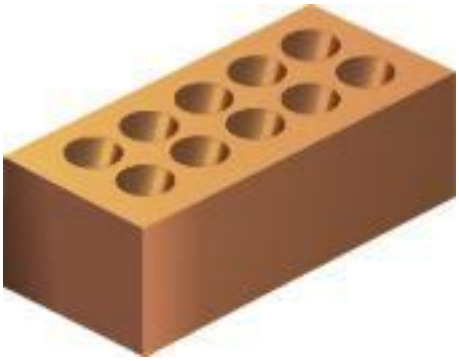
- Low population density means "felt earthquakes" may not be reported. An interesting earthquake "swarm" has been moving northwards through the Central Wheatbelt for many years. Because movements are not severe and few people or properties are affected the phenomenon is poorly reported.

- Access to seismic information for "small" quake information. Australian Seismometers in Schools project has placed seismometers in 28 schools (October 2013) across Australia. These can be used to monitor activity across the Indo-Pacific region. Presently (2013) six schools in Bussleton, Carnarvon, Kalgoorlie, Karratha, Kulin and Perth are hosting themhttp://rev.seis.sc.edu/stationList.html
www.ga.gov.au/earthquakes/staticPageController.do?page=earthquake-activity

Most Australian earthquakes happen in the upper 20km of the crust where rocks are cold and brittle. Some faults allow almost constant friction free movement whilst others build up stress until it is released in damaging movement. When rocks are required to move past each other along a fault line they will resist until the force applied exceeds "limiting friction". This results in sporadic jerky movements which are felt as earthquakes. Movement is greatest at the margins of crustal plates where noticeable earthquakes are felt.
Students may experience this jerky movement by pushing two bricks past each other or by pushing a brick over a cement surface.
www.ga.gov.au/earthquakes/staticPageController.do?page=earthquake-activity

Materials per student or group:

- 1 brick and a cement or hard rough surface
- String
- Newton spring balance
- Water (bucket)



What can be done to make this experiment a "Fair Trial"?
Repeat the experiment.

Method:

1. Trial your activity to ensure your equipment will result in data that is accurate (using equipment which will record the data effectively) and precise (to two decimal places).

2. Tie the string round the brick and lift it freely into the air. Read the force required to move it through air (3 readings).

3. Place the brick on concrete and increase force until it will move it across the surface of the concrete. (3 readings)

What was the difference in force between rock and air and rock and rock?
Less energy was required to lift the block through air.

How could this experiment be improved to model movement along a fault line?
Rocks on either side of a fault line would not be smooth and fault lines are not always simple straight lines.

4. Wet the surface of the concrete and repeat step 3. What do you observe? Less force is required to get the block moving and it moves faster.

What effect do you think water would have on fault movement?
More frequent and less destructive movement.

Since Australia and its continental shelf lie well within the greater Australian Continental Plate we do not suffer from the major quakes felt on continental plate margins where the crust may be crumpled upwards, subducted downwards or sheared against another continental plate. Adjustments to stress within our plate causes earthquakes however.

Most Australian earthquakes happen in the upper 20km of the crust where rocks are cold and brittle. Some faults allow almost constant friction free movement whilst others build up stress until it is released in damaging movement. When rocks are required to move past each other along a fault line they will resist until the force applied exceeds "limiting friction". This results in sporadic jerky movements which are felt as earthquakes. Movement is greatest at the margins of crustal plates where noticeable earthquakes are felt.
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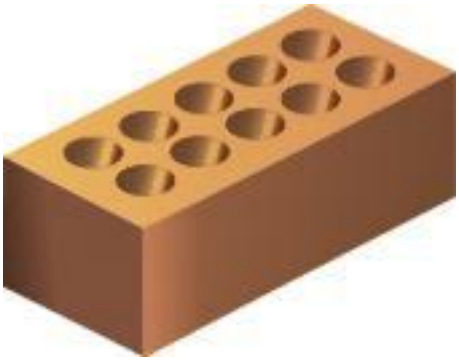


Materials per student or group:

- 1 brick and a cement or hard rough surface to pull it over
- String
- Newton spring balance
- Water (bucket)

What can be done to make this experiment a "Fair Trial"?
Repeat the experiment.

Method:

1. Trial your activity to ensure your equipment will result in data that is accurate and precise.

2. Tie the string round the brick and lift it freely into the air. Read the force required to move it through air (3 readings).

3. Place the brick on concrete and increase force until it will move it across the surface of the concrete. (3 readings)

What was the difference in force between rock and air and rock and rock?

_____

How could this experiment be improved to model movement along a fault line?

_____

_____

4. Wet the surface of the concrete and repeat step 3. What do you observe?

_____

_____

What effect do you think water would have on fault movement?

_____

Wave Energy Transfer - Teacher Notes

Seismic waves are energy waves released during earthquakes. When seismic waves pass through rock, particles are moved to release stress. Shock waves travel in all directions away from the source and are impeded and deflected by the materials (media) they travel through. NB Although "media" commonly refers to mass communications (radio, TV internet etc.) it is used in Science when referring to more than one intervening substance through which energy is transmitted.

Teacher Demonstration 1

AIM **To demonstrate that energy waves move in all directions away from source**

Materials

- A large container of water
- A marble or small stone

Method

1. Drop the stone into the water and ask students to note that waves move away from source in all directions.

Student observations

1. Describe what happened when the falling object hit the water surface.
When the stone hit the surface of the water waves moved away from the point of impact.

2. What form of energy form was the potential energy of the stone converted to?
Potential energy from the stone was converted into kinetic energy of the water (waves).

Teacher Demonstration 2 (or student activity)

AIM **To demonstrate that waves travel in pulses through a medium**

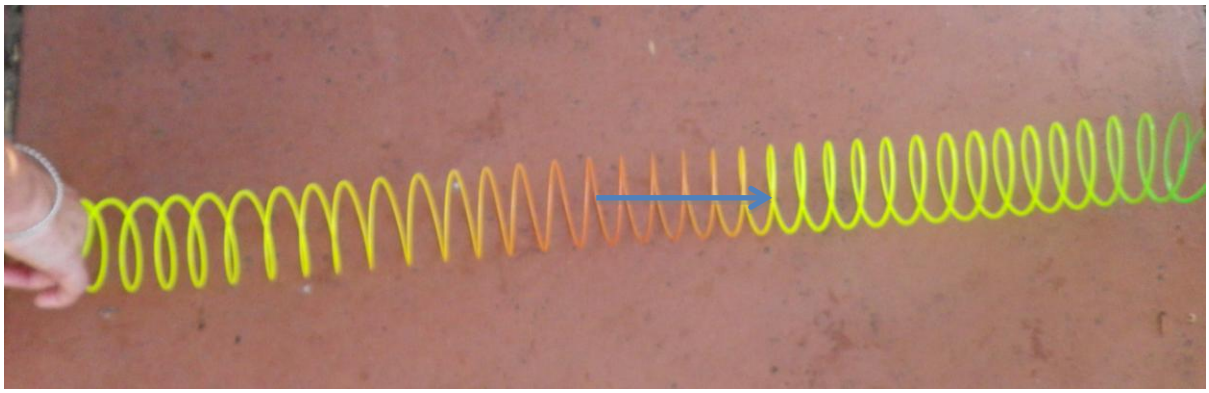
Materials

- A table, desk or concrete path
- A slinkie (coiled steel or plastic). *Slinkies can easily become tangled and distorted if students do not take care. A little directed practice prior to the activity or a teacher demonstration may be advisable.*
- Two students or one teacher and a student

Method

Bunch up a handful of coils at one end of the slinkie.
Ask another to stretch (but not overstretch) the slinkie and hold the other end firmly.
Lower the slinkie until it just touches the hard surface below.
Release the bunched coils and watch the compressed zone (rarefaction) travel along the slinkie to the other end.
Repeat and discuss.

Wave Energy Transfer - Teacher Notes



Student observations

3. When the bunch of coils was released from one end, what happened to the slinkie?
The energy travelled as a zone of compacted coils away from the released end.

4. Energy travels as a zone of compaction within the extended coil. Repeat the experiment and check if this statement agrees with your observation. Does it? YES

5. Did the length of the slinkie increase or decrease as the energy pulse travelled along it?
The length remained constant.

A medium is the material that energy waves can pass through. E.g. Light waves pass through the media of air and water. What medium did the elastic energy of compression travel through?
The slinkie, a solid.

Student Activity

Waves are energy passed on through movement of molecules (vibration). Solids are denser than liquids and liquids are denser than gasses. Waves travel faster through solids than air because the molecules are closer together because the forces of attraction between their molecules are stronger than their kinetic energy. A common student misconception is that compression waves only travel through the air. The simple activity below will demonstrate to students that compression waves can pass through solids.

AIM **To demonstrate that energy waves travel through solid media such as the Earth**

Materials

- A wooden desk
- A ruler

Method

1. Lay the ruler to the bone behind your ear (mastoid process)
2. Lay the other end of the ruler onto your desk
3. Scratch underside of desk directly below the ruler
4. Repeat scratching without the ruler

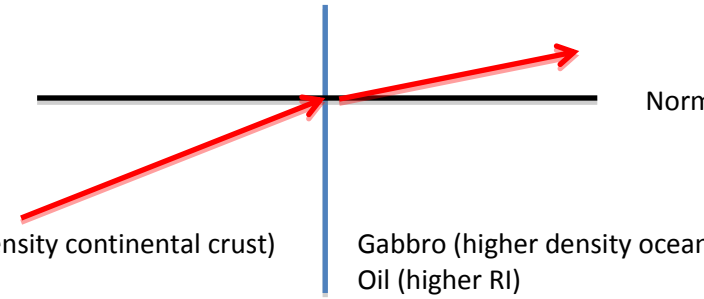
Student Observations

6. What did you observe?
When the ruler made a solid connection between the ear and the desk scratching could be heard. When the only connection between the desk and the ear was a gas (air) no sound could be heard.

7. Why do compression waves such as sound travel more easily in a solid than a liquid?
Kinetic Energy theory, learned in Year 8 suggests that molecules are more closely bound together in a solid as the forces of attraction exceed kinetic energy. It is therefore easier to pass movement energy from one molecule to another.

When a wave passes from one medium into another with a higher refractive index, RI (generally a more dense medium) the wave is bent or refracted towards the normal (a plane at right angles to the interface between the two media)

Direction of wave (light or seismic energy) movement



In the school laboratory light energy is easier to manipulate than seismic energy. You may wish to hit one end of a brick with a hammer. Students can feel the compression energy transmitted through the solid brick to their fingers.

Teacher Demonstration 3

<u>AIM</u> To demonstrate refraction of light at the interface of two different media

Materials

- Tall glass beaker or measuring cylinder
- Pencil, knitting needle, pencil or metal rod
- Water
- Cooking oil

Method

1. Place a narrow rod or pencil into a container with two liquids of different densities.

Student Observations

8. Draw what the pencil looks like before it is placed into the liquids in the glass.

9. Draw what the pencil looks like when it is partially immersed in liquids with different refractive indices (different media)

10. What appears different when the pencil is viewed through different media?
Parts of the pencil appear both displaced and wider than it is in air. The greatest displacement and distortion was through oil.

11. Name the different media through which light energy was transmitted.
Water, oil and air.

12. Earthquakes energy (seismic waves) is transmitted through different density layers in the Earth. Would you expect it to be refracted (bent) Yes. The different layers would refract the waves.

Interesting Fact
When Aboriginal or other hunting people spear fish, they must compensate for refraction. Light rays are bent passing from water to air. The apparent position of a fish will not be its actual position. After a period of learning, a hunter's brain makes habitual adjustments.
This skill is not necessary when spearfishing underwater as both the hunter and the prey are in the same medium.

Beautiful petroglyph of a fish from Murujuga (Burrup Peninsula) on the Pilbara coast.

Refraction of light can also be demonstrated by adding a little milk to cloud some water in a large beaker. A narrow beam of light from a torch or Hodgekin's Light Box will be refracted at the milk/air interface.

Fun Extension - Teacher Demonstration

Laboratory glass and glycerol have almost the same refractive indices. There are two glass prisms in this photograph. One is outside the glass but the other is invisible within the liquid. Clear colourless glass marbles will also disappear in glycerol.

Suggested **materials**

- Two glass beakers
- Water
- Glycerol (sometimes sold as glycerine)
- Two glass objects (stirring rod, lens, broken fragment)
-

Ask students to view what happens when one object is placed in a beaker with water and another placed in the beaker with glycerol

What happened when the glass object was placed in water? The object was clearly visible.

What happened if you placed the glass object in glycerol? The object seems to disappear.

In movies people hide diamonds in ice cubes in their freezers. Does this work? Explain your answer using the data below.
No. The RI of diamond is 2.42, which is very different to the RI of ice 1.31. Diamonds would be obvious within the ice.

Refractive indexes of various transparent materials

Air	1.00	Plain glass	1.45
Ice	1.31	Lab. glass	1.47
Water	1.33	Diamond	2.42
Glycerol	1.47	Methylene iodide	1.74

How could a sneaky science student find out find out if cheaper stones such as cubic zirconium or spinel had replaced diamonds in a damaged bracelet? (This might require some Internet searching).

Spinel (RI 1.7) will “disappear” when the bracelet is immersed in methylene iodide.
Few liquids have RIs as high as diamond. However another diamond will scratch spinel, as it is harder. The softer stones are fakes.

Wave Energy Transfer – Student Activity

Seismic waves are energy waves released during earthquakes.

1. **Teacher Demonstration - Seismic waves move in all directions from the source**

1. Describe what happened when the falling object hit the water surface.

_____

_____

2. To which form of energy was the object's potential energy converted?

_____

2. **Teacher Demonstration (or student activity) - Waves energy can travel in pulses through a medium.**

Although "media" commonly refers to mass communications (radio, TV internet etc.) it is used in Science when referring to more than one intervening substance (medium) through which energy is transmitted.

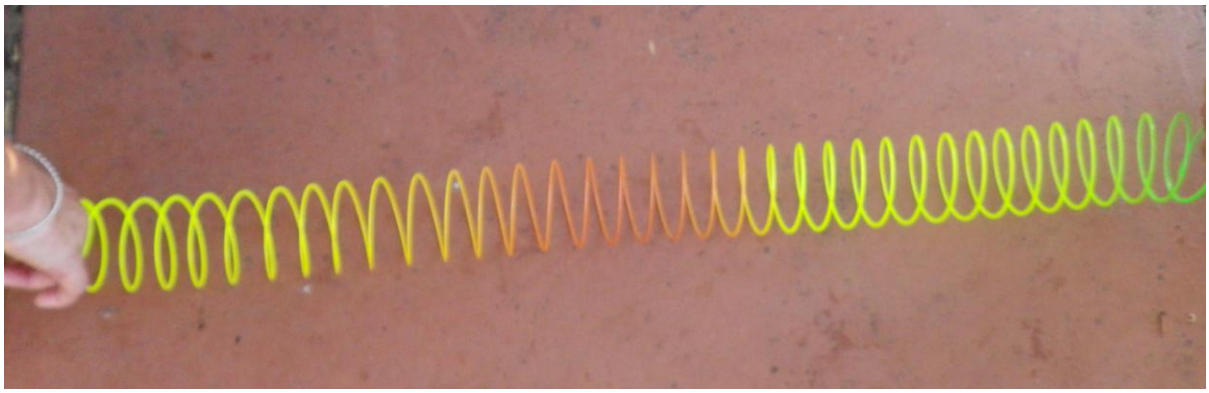
Materials

- A table, desk or concrete path
- A slinkie (coiled steel or plastic).
- Two students or one teacher and one student

Method

1. Bunch up a handful of coils at one end of the slinkie.
2. Ask another to stretch (but not overstretch) the slinkie and hold the other end firmly.
3. Lower the slinkie until it just touches the hard surface below.
4. Release the bunched coils and watch the compressed zone travel along the slinkie to the other end.
5. Repeat and discuss.

Wave Energy Transfer – Student Activity



3. When the bunch of coils was released from one end, what happened to the slinkie? How was the energy transferred?

_____

_____

4. Energy travels as a zone of compaction within the extended coil. Repeat the experiment and check if this statement agrees with your observation.

Does it? _____

5. Did the length of the slinkie increase or decrease as the energy pulse travelled along it?

_____

A medium is the material that energy waves can pass through. E.g. Light waves pass through the media of air and water. Through which medium did the elastic energy of compression travel?

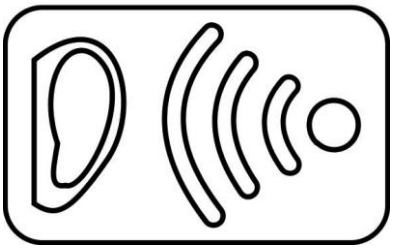
_____

Student Activity
Waves are energy passed on through movement of molecules (vibration).

AIM **To demonstrate that energy waves travel through solid media such as the Earth**

Materials

- A wooden desk
- A ruler



Method

1. Lay the ruler to the bone behind your ear (mastoid process)
2. Lay the other end of the ruler onto your desk
3. Scratch underside of desk directly below the ruler
4. Repeat scratching without the ruler

6. What did you observe?

_____

_____

7. Why do compression waves such as sound travel more easily in a ***solid*** than a ***liquid***?

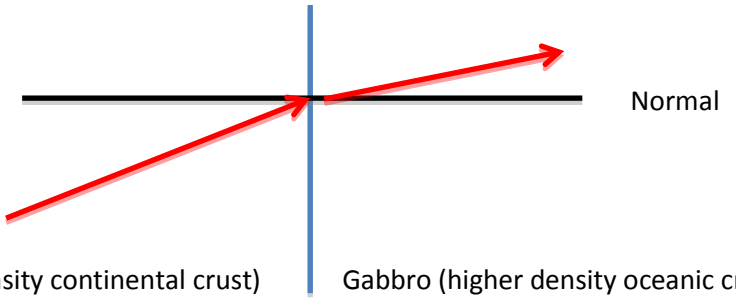
_____

_____

_____

When a wave passes from one medium into another with a higher refractive index, RI (generally a more dense medium) the wave is bent or refracted towards the normal (a plane at right angles to the interface between the two media)

Direction of wave (light or seismic energy) movement



Sandstone (low density continental crust)
Water (Low RI)

Gabbro (higher density oceanic crust)
Oil (higher RI)

In the school laboratory light energy is easier to manipulate than seismic energy!

Teacher Demonstration 3 - Refraction (bending) of light waves

8. Draw below what the pencil looks like before it is placed into the liquids

9. Draw what the pencil looks like and label the differences which appear to happen when it is partially immersed in liquids with different refractive indices (different media).

10. What appears different when the pencil is viewed through different media?

_____

11. Name the different media through which light energy was transmitted.

_____

12. Earthquakes energy waves are transmitted through different density layers in the Earth. Would you expect them to be refracted (bent)? Explain your answer.

_____

_____

Interesting Fact

When Aboriginal or other hunting people spear fish, they must compensate for refraction. Light rays are bent passing from water to air. The apparent position of a fish will not be its actual position. In time a hunter's brain makes habitual adjustments.
This skill is not necessary when spearfishing underwater as both the hunter and the prey are in the same medium.

Beautiful petroglyph of a fish from the Burrup Peninsula on the Pilbara coast.

Fun Extension - Teacher Demonstration

What happened when glass was placed in water? _____

What happened when glass was placed in glycerol? _____

In movies people hide diamonds in ice cubes in their freezers. Will this work? Explain your answer using the data below.

_____

_____

RI air	1.00	RI glycerol	1.47	RI diamond	2.42
RI ice	1.31	RI plain glass	1.45	RI methylene iodide	1.74
RI water	1.33	RI Lab. glass	1.47		

Extra for experts

How could a sneaky science student find out if cheaper stones such as cubic zirconia or spinel had replaced diamonds in a damaged bracelet? (This might require an Internet search.)

Body Waves (S&P) - Teacher Notes

Seismic waves are energy waves released during earthquakes. Stress built up during tectonic movement builds up until it overcomes limiting friction and is released as a seismic wave. When seismic waves pass through rock, particles are moved to release stress. These shock waves travel in all directions away from the source and are impeded and deflected by the materials they travel through. A background to wave movement is provided in the "Wave Energy Transfer" activities. Their point of origin within the Earth is called the focus. The point on the surface directly above this is called the epicentre. In general, the shallower the earthquake the more damaging it is liable to be. The worldwide distribution of earthquakes is remarkably similar to the location of constructive and destructive plate boundaries.

There are two kinds of seismic waves: body waves and surface waves.

BODY WAVES (S&P) are waves that travel through the body of the Earth.

P waves are compressions that pulse through rock. The compressive wave of energy moves on but molecules return to their original position. Because the waves are affected by density, they are slowed and deflected by the Earth's dense core. This results in a donut shaped shadow zone formed on the other side of the planet where no p waves are registered.
In most earthquakes the P waves are the first to be felt. Often there is an accompanying sonic boom. Sound is the result of compression and refraction of air molecules when p wave energy is transmitted across the rock-air interface at the surface.

S waves are also known as secondary, shake or transverse waves. These are transmitted by a sideways or up and down movement. These cannot travel through liquids and have a shadow zone directly on the other side of the planet where no seismicity is felt. This characteristic was used to infer that the outer core of the Earth was liquid. These can be demonstrated by moving a rope from side to side. The S waves usually arrive a few seconds later than the P waves. They rattle and shake the ground vertically and horizontally.
http://www.pbs.org/wnet/savageearth/animations/earthquakes/main.html

(There are also surface waves (Love waves (L) and Rayleigh (R)). These travel across the surface of the planet lifting and dropping the earth like ripples across a pond and cause major damage to humans and their property)

For animations of these wave forms visit:
http://www.pbs.org/wnet/savageearth/animations/earthquakes/main.html

Name	Travels	Passes through	
P	Compression longitudinal movement	Solid and molten rock, liquids and air.	Fastest wave (speed of sound)
S	Transverse (shearing) movement	Solid rock only	Slower than P but more damaging
L & R	At right angles to S & P on surface in a rolling motion	Surface rock	Devastating

More resources available at: http://www.iris.edu/hq/retm teachable earthquake moments

Body Waves (S&P) - Teacher Notes

<u>AIM</u> **To demonstrate the difference between S and P body waves**

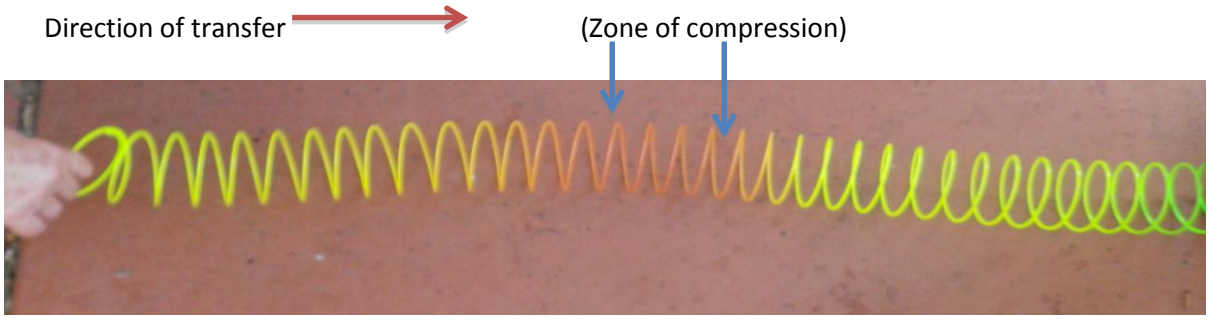
This activity needs room and if students are performing it is best done outside on a smooth surface such as a concrete veranda or pathway.

Materials

- Three students or two students and a teacher
- A piece of chalk or masking tape to mark positions
- A measuring tape of metre ruler
- A long slinkie
- A piece of rope or cord the same length as the partially extended slinkie
- A stopwatch or accurate timepiece

Part A The P wave. COMPRESSION OR PRIMARY WAVES

P waves are compressions that are transmitted through solids, liquids and gasses. P waves are the result of a zone of compressed waves being transferred along the direction of wave travel.
P waves are called primary waves because they are the first to arrive after an earthquake.



A scientist often trials experiments before formal testing to find out which variables have not been controlled and to work out how the experiment can be improved. These are sometimes called "trial" or "dummy" runs.

Trial Run – (groups of three)

Method

1. Bunch a few coils of the slinkie in one student's hand at one end and let another student extend the slinky.
2. Mark the position of the ends with chalk or masking tape.
3. Measure the length of the slinky
4. Release the bunched coils and observe.
5. Measure the time taken for the compression wave to travel along your slinky

How can this experiment be improved?

Share ideas with your group to control variables and make sure the results are accurate and precise.
All slinkies should be in the same condition, of the same length and used over the same surface.
The length of the extended slinky should be adjusted to best observe the movement of the compression wave.
All experimenters should have exactly the same number of coils bunched in their hands.

Body Waves (S&P) - Teacher Notes

The experiment should be repeated and the results averaged.
Accuracy and precision requires the use of an accurate timepiece that has sufficient discrimination to be precise and a user that observes and responds quickly.

Write your improved experiment below. Carry it out and list your observations

AIM _____

Materials

Method

Observations

Speed = Distance / Time

Conclusion The speed of the wave was _____**Units are essential (m/s)**_____
The speed of the P wave will depend on the material of the slinky and friction with the surface you are working on.

P wave - Student Activity 2

Rules

1. Each student only takes four steps, two to the right and then two to the left to return to their original position.

2. There are never more than three students bunched up at any time.

Method

1. Students stand about 1 step (30 cm) apart.
2. Someone loudly counts the seconds.
3. On the first second the first student takes one step to their right to join the second student.
4. On the second count both these students take one step to the right to join the third student. This group of three is the compression wave.
5. On the third second the first student starts their return to their original position at one step per second while the remaining pair move one step to the right to join the next student and maintain the compression of three.
6. This pattern continues to the end of the line.
7. Each student returns to their original position after the wave moved on.
8. It is easiest to start with 8 students in a line. Place another line behind the first line to pick up the pattern of movement.
9. Finally place students in a circle and send a series of waves through them.

Body Waves (S&P) - Teacher Notes

Direction of wave transmission

1	2	3	4	5	6	7	8
	1+2	3	4	5	6	7	8
		1+2+3	4	5	6	7	8
	1		**2+3+4**	5	6	7	8
1		2		**3+4+5**	6	7	8
1	2		3		**4+5+6**	7	8
1	2	3		4		**5+6+7**	8
1	2	3	4		5		**6+7+8**
1	2	3	4	5		6	7+8
1	2	3	4	5	6	7	8

P wave - Student Activity 3

To demonstrate that compression waves in air can create a sonic boom clap hands together to cause compressed air and noise.

Part B The S wave. Secondary or Shear wave

S waves are slower than P waves and only travel through solids. When an S wave passes, particles move at right angles to the direction of transmission. S waves only travel through solids so cannot be transmitted through the molten outer core. This means there is a "shadow zone" where no secondary waves are felt on the other side of the Earth from the focus.

AIM **To replicate an S wave and measure its speed of transmission.**

Materials

- Two students
- A piece of rope or cord as long as the extended slinky in the previous experiment
- Something to tie one end of the rope to e.g. a door handle, seat back or fence line

Method

1. Lay the rope straight between the markings of the previous experiment
2. Two students hold the ends firmly
3. One of these students briskly flicks a single vertical wave of rope towards the other end
4. The second student measures time taken for the transmitted S wave to travel the length of the rope
5. Repeat measurements and find the average speed of transmission of S waves.
6. Compare these results with those from the previous (p wave) experiment

Body Waves (S&P) - Teacher Notes

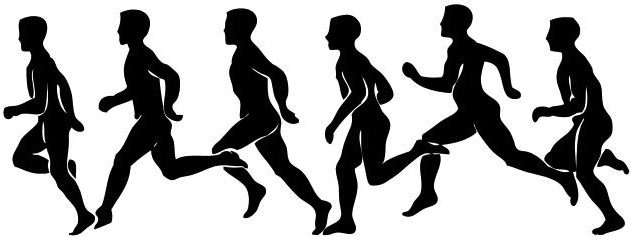
Observations on S wave motion

Trial	Time (s)	Distance (m)	Speed (m/s)
1			
2			
3			
		Average	

Discussion

Which waveform is transmitted faster? P waves
S waves can be twice as slow as P waves. This may not be obvious over a short distance with inaccurate timekeeping.

Describe the difference in mode of transmission between P and S waves that you could see.
P waves travelled as compressions along the same direction as the wave front. S waves moved as displacement at perpendicular/at right angles to the direction of movement



What should you do if you feel a P wave arrive? Take cover under a table or in the toilet and wait for the arrival of the S wave and more destructive surface waves which follow them

Average speed of teenager running	about 10 to 15km/hour	3-4m/s
Average speed of P wave	330 m/s in air 450m/s in water 500m/s in rock (granite)	
Average speed of S wave	about 60% of P wave S waves cannot travel through liquids or gasses they rely on resistance to shear the medium they pass through.	2-3m/s
Average speed of Stealth bomber	1,010km per hour	280.5m/s

It can however fly "through the sound barrier" causing a sonic boom

Speed of sound	343.2m/s

Materials
Students will have to convert the data above to uniform units for comparison. Scrap paper and calculators may be necessary.

If you realise a particularly devastating earthquake was about to strike, could you outrun or fly away from it? No. Running would be at least one hundred times too slow. Even the fast Stealth bomber could not consistently outrun the waves.

Body Waves (S&P) - Teacher Notes

Why do P waves travel faster in rock than in air (HINT kinetic energy)
In solids molecules are closer together and it is easier to pass on energy from molecule to molecule.

S wave - Student Activity 2

Students can either perform the "Mexican wave" movement beloved by soccer fans by standing up and sitting down one second after the student on their left starts moving. The wave rolls along the line of students. Seated students can just raise and lower their arms with a similar one-second delay.

Many simple animations of P and S waves can be found on the Internet

Extension

Students can lay both P and S wave experiments side by side. They can estimate which form of wave transmission looks faster by observing which reached the other end first.

Why is this experiment scientifically flawed?
This experiment is inaccurate because it relies on the reaction rates of four different people.

Information about seismic monitoring in Australia can be found at:
http://www.ga.gov.au/hazards/our-capabilities/monitoring/earthquake-monitoring.html

Seismometers in Schools project at: https://www.facebook.com/ausisnetwork

Body Waves (S&P) - Student Activities

Seismic waves are energy waves released during earthquakes. Stress released during tectonic movement builds up until it overcomes limiting friction and is released as a seismic wave. When seismic waves pass through rock, particles are moved to release stress. These shock waves travel in all directions away from the source and are impeded and deflected by the materials they travel through.

There are two kinds of seismic waves:

1. **BODY WAVES (S&P)** are waves that travel through the body of the Earth.

   P waves are compressions that pulse through rock. In most earthquakes the P waves are the first to be felt. Often there is an accompanying sonic boom.

   S waves are also known as secondary, shake or transverse waves. These are transmitted by a sideways or up and down movement. S waves usually arrive a few seconds later than the P waves. They rattle and shake the ground vertically and horizontally but cannot travel through liquids.
   http://www.pbs.org/wnet/savageearth/animations/earthquakes/main.html

2. There are also **surface waves** (Love waves (L) and Rayleigh waves (R)). These travel across the surface of the planet lifting and dropping the earth like ripples across a pond and cause major damage to humans and their property.

For animations of these wave forms visit:
http://www.pbs.org/wnet/savageearth/animations/earthquakes/main.html

AIM **To demonstrate the difference between S and P body waves**

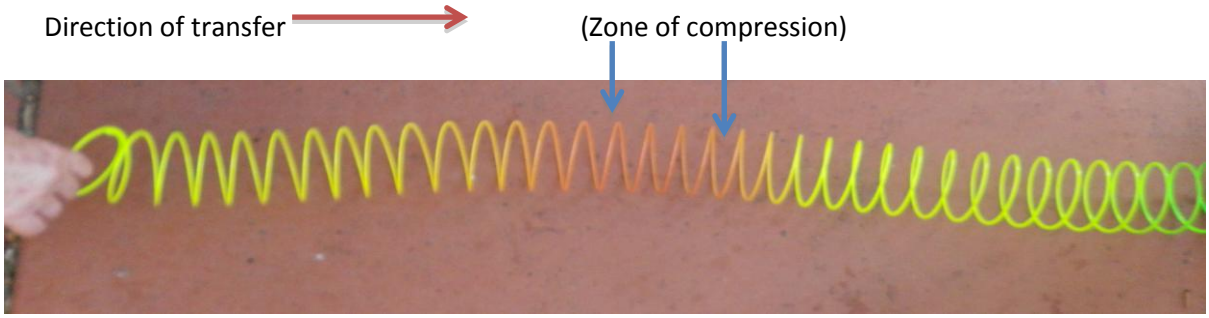
Materials

- Three students
- A piece of chalk or masking tape to mark positions
- A measuring tape or metre ruler
- A long slinkie
- A piece of rope or cord the same length as the partially extended slinkie
- A stopwatch or accurate timepiece

Part A The P wave. COMPRESSION OR PRIMARY WAVES

P waves are compressions that are transmitted through solids, liquids and gasses. P waves are the result of a zone of compressed waves being transferred along the direction of wave travel.
P waves are called primary waves because they are the first to arrive after an earthquake.

Body Waves (S&P) - Student Activities



Scientists often trial experiments before formal testing to find out which variables have not been controlled and to work out how the experiment can be improved. These are sometimes called "trial runs" or "dummy" runs.

Trial Run - You will be working in groups of three

1. Bunch a few coils of the slinkie in one student's hand at one end and let another student extend the slinky.
2. Mark the position of the ends with chalk or masking tape.
3. Measure the length of the slinky
4. Release the bunched coils and observe.
5. Measure the time taken for the compression wave to travel along your slinky

How can this experiment be improved? Share ideas with your group to control variables and make sure the results are accurate and precise

_____

_____

Write your improved experiment below. Carry it out and list your observations

AIM _____

Materials

_____

_____

_____

Method

_____

_____

_____

Body Waves (S&P) - Student Activities

Observations

_____ **Speed = Distance / Time**

_____

_____

Conclusion The speed of the wave was _____

_____

_____

P wave - Student Activity 2

Rules

For each wave pulse:

1. Each student only takes four steps, two to the right and then two to the left before returning to their original position.
2. There are never more than three students bunched up at any time.

Method

1. Students stand about 1 step (30 cm) apart.
2. Someone loudly counts the seconds.
3. On the first second the first student takes one step to their right to join the second student.
4. On the second count both these students take one step to the right to join the third student. This group of three is the compression wave.
5. On the third second the first student starts their return to their original position at one step per second while the remaining pair move one step to the right to join the next student and maintain the compression of three.
6. This pattern continues to the end of the line.
7. Each student returns to their original position after the wave moved on.

Direction of wave transmission

1	2	3	4	5	6	7	8
	1+2	3	4	5	6	7	8
		1+2+3	4	5	6	7	8
	1		**2+3+4**	5	6	7	8
1		2		**3+4+5**	6	7	8
1	2		3		**4+5+6**	7	8
1	2	3		4		**5+6+7**	8
1	2	3	4		5		**6+7+8**
1	2	3	4	5		6	7+8
1	2	3	4	5	6	7	8

Body Waves (S&P) - Student Activities

Part B The S wave. Secondary or Shear wave

S waves are slower than P waves and only travel through solids. When an S wave passes, particles move at right angles to the direction of transmission. S waves only travel through solids

AIM **To replicate an S wave and measure its speed of transmission.**

Materials

- Two students
- A piece of rope or cord as long as the extended slinky in the previous experiment
- Something to tie one end of the rope to e.g. a door handle, seat back or fence line

Method

1. Lay the rope straight between the markings of the previous experiment
2. Two students hold the ends firmly
3. One of these students briskly flicks a single vertical wave of rope towards the other end
4. The second student measures time taken for the transmitted S wave to travel the length of the rope
5. Repeat measurements and find the average speed of transmission of S waves.
6. Compare these results with those from the previous (p wave) experiment

Observations on S wave motion

Trial	Time (s)	Distance (m)	Speed (m/s)
1			
2			
3			
		Average	

Discussion

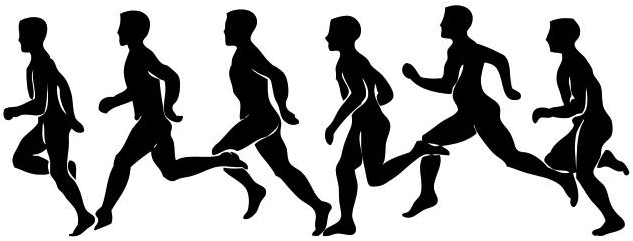
Which wave form travels or is transmitted faster? _____

Describe any difference in mode of transmission between P and S waves that you could see.

_____

_____

Body Waves (S&P) - Student Activities



What should you do if you feel a P wave arrive? _____

<u>Information to help you decide what to do during an earthquake</u>

Average speed of teenager running	about 10 to 15km/hour
Average speed of P wave	330 m/s in air
	450m/s in water
	500m/s in rock (granite)
Average speed of S wave	about 60% of P wave
Average speed of Stealth bomber	1,010km per hour
Speed of sound	343.2m/s

Materials

1. Convert the data above to the same units to allow easy comparison.

If you realise a particularly devastating earthquake was about to strike, could you outrun or fly away from it? _____

Why do P waves travel faster in rock than in air (HINT kinetic energy) _____

_____

What should you do if you feel a P wave arrive? _____

_____

S waves can be twice as slow as P waves.

S wave – Student Activity 2

Students can either perform the "Mexican wave" movement beloved by soccer fans by standing up and sitting down one second after the student on their left starts moving. The wave rolls along the line of students.
Seated students can just raise and lower their arms at with a similar one-second delay.

Body Waves (S&P) - Student Activities

Extension

Students can lay both P and S wave experiments side by side. They can estimate which form of wave transmission looks faster by observing which reached the other end first.

Why is this comparison scientifically inaccurate? _____

_____

_____

_____

Information about seismic monitoring in Australia can be found at:
http://www.ga.gov.au/hazards/our-capabilities/monitoring/earthquake-monitoring.html

Seismometers in Schools project at: https://www.facebook.com/ausisnetwork

Surface Waves (L&R) – Teacher Notes

Seismic waves are energy waves released during earthquakes. These shock waves travel in all directions away from source and are impeded and deflected by the materials they travel through. A background to wave movement is provided in the "Wave Energy Transfer" activities.

There are two kinds of seismic waves:

1. **Body waves** travel through the body of the Earth. **P** waves are compressions that pulse through rock. **S** waves are also known as secondary, shake or transverse waves.

2. **Surface waves** are triggered when P and S waves are deflected to travel along the surface of the Earth. They are slower but much more destructive than body waves. Love (**L**) waves are polarised shear waves and Rayleigh waves (**R**) cause the ground to roll.

Movement from these waves can cause sediments to behave as a liquid. Liquefaction is particularly pronounced in poorly sorted sediments containing water such as those lying in old river channels in Canterbury in New Zealand. Whole suburbs have been rendered uninhabitable as houses sank into the ground and services were twisted and fractured. Because future earthquakes might cause the same problem building in these zones is prohibited.

AIM **To model liquefaction during an earthquake**

Materials per student or group

- A large stone, block of wood or Lego house.
- A beaker or plastic drink cup
- Sufficient dry seeds (sunflower, rice, lentils etc.) or dry clean sand to half fill the beaker
- Water

Method
1. Half fill the beaker with seeds.
2. Place the "house" or rock on top.
3. Shake the beaker rapidly side to side without spilling the seed.
4. Observe and report
5. Add water and repeat

Observation
What happened to the "house" when the beaker was shaken?
The "house" started to sink into the ground

What happened when water was added to the dry material?
The house sank more rapidly

Surface Waves (L&R) – Teacher Notes

The old hymn says:
"Build on the rock, the rock that ever stands
Oh! Build on the rock and not upon the sands
You need not fear the storm or the earthquake's shock
You are safe for evermore if you build on the rock!"

Will building on a rock make your house safe from earthquakes?
It might save the house from surface wave induced liquefaction but it could still be shaken by S and P body waves.

Surface Waves (L&R) – Student Activity

Seismic waves are energy waves released during earthquakes. There are two kinds of seismic waves:

1. **Body waves** travel through the body of the Earth. **P** waves are compressions that pulse through rock. **S** waves are also known as secondary, shake or transverse waves.

2. **Surface waves** are triggered when P and S waves are deflected to travel along the surface of the Earth. They are slower but much more destructive than body waves. Love (**L**) waves are polarised shear waves and Rayleigh waves (**R**) cause the ground to roll.

Movement from surface waves can cause sediments to behave as a liquid. During the 2011 earthquake in Canterbury in New Zealand whole suburbs were rendered uninhabitable as houses sank into the ground and water, electricity and sewage services were twisted and fractured. Because of the possibility of more earthquakes, building in these zones is prohibited.

AIM **To model liquefaction during an earthquake**

Materials per student or group

- A large stone, block of wood or Lego house.
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Method

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3. Shake the beaker rapidly side to side without spilling the seed.
4. Observe and report
5. Add water and repeat

Observation

What happened to the "house" when the beaker was shaken? _____

_____

_____

What happened when water was added to the dry material? _____

_____

_____

Surface Waves (L&R) – Student Activity

The old hymn says: *"Build on the rock, the rock that ever stands*
Oh! Build on the rock and not upon the sands
You need not fear the storm or the earthquake's shock
You are safe for evermore if you build on the rock!"

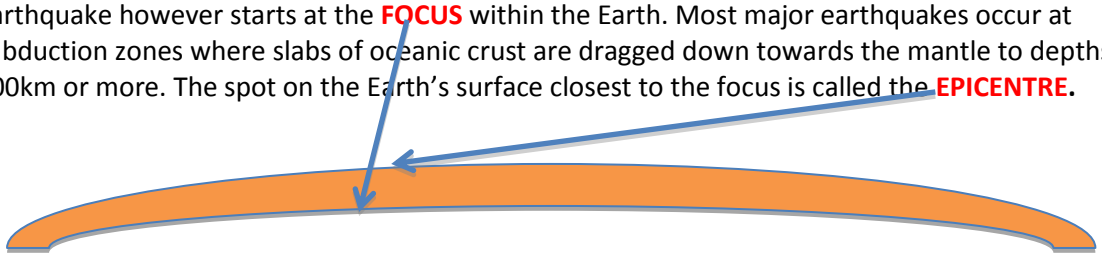
Will building on a rock make your house safe from earthquakes? Explain your answer. _____

_____

_____

Locating an Earthquake – Teacher Notes

Being human we tend to think of an earthquake only as it affects us on the surface of the Earth. The earthquake however starts at the **FOCUS** within the Earth. Most major earthquakes occur at subduction zones where slabs of oceanic crust are dragged down towards the mantle to depths of 700km or more. The spot on the Earth's surface closest to the focus is called the **EPICENTRE**.



Humans only usually feel earthquakes registering above magnitude 3. Other animals and birds are more sensitive and will display changed behaviour because they can feel early tremors.
Australia lies well away from its plate boundary but we still register seismic movement as our plate adjusts to external seismic movement.

This might be a good time to remind students of your school's rules for handling emergencies (such as earthquakes). Most schools have a system of bells, whistles or hooters which signal evacuation to an open space such as the sports grounds. Another system of bells etc. signal "All clear".

The cliffs behind collapsed into the Redcliffs school's back yard during the 2011 Christchurch earthquake. Rock rolled and crashed right up to the back door. There was no damage to the fabric of the school and nobody was at school at the time

What are your school's rules about safety during earthquakes? Local rules apply

How much time do you have to reach the safe assembly point after feeling the first P waves arrive? Teachers may choose to send a couple of fast walking students with watches or estimate the time themselves.

Seismic scenario

We know

1. P waves are the fastest waves to arrive. Their average speed is 7km/s.
2. S waves arrive next. Their average speed is 4km/s.
3. Very destructive surface waves may arrive later.

Locating an Earthquake – Teacher Notes

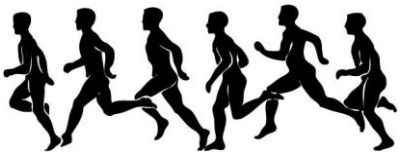
Materials per student

- An atlas or map of the Indo-Pacific region
- A pencil (Not 2B)
- A ruler
- A pair of compasses
- A calculator
- An eraser
- Scrap paper

An earthquake is triggered at a plate boundary near Indonesia 3,500km away.

How long will it take for the P wave to reach your school? 3,500 ÷ 7 = 500 s

How long will it take for the S wave to reach your school 3,500 ÷ 4 = 875s



Being a sensible science student you know that you should evacuate before the S wave arrives.

How much time do you have to get from the classroom to the evacuation point before the S wave hits? Use the space below for your calculations
875 – 500 = 355s or 5 minutes and 55 seconds

How long would it take you to get safely to your assembly point?
Local time. Students are often surprised that they should move in a quiet orderly fashion in an emergency, leave their bags and support less able students.

If you do not have sufficient time to get out of the classroom, what should you do to remain as safe as possible?

Take shelter under desks (best option), doorways and in toilet cubicles.
Switch off gas, water and electricity at mains.
Keep away from windows, shelving, glassware and chemicals.
Keep calm and support others
Stay interested in what is happening and time everything. This can be useful to estimate how far away the earthquake might be

The distance from an earthquake's epicentre can be roughly inferred by the interval in time between the arrival of P waves and S waves.

Interval in minutes	Distance in kilometres
1.5	900
3	1,800
5	3,300

An earthquake was registered on your school's seismograph. The interval between P and S wave arrivals was 4 minutes. Estimate the distance to the epicentre using the information in the table and the graph paper provided.

Locating an Earthquake – Teacher Notes

What kind of graph should this be? A line graph

What should be on the horizontal axis? Time

What should be on the vertical axis? Distance to epicentre

What should the title be? Graph comparing distance to epicentre with interval between P & S waves

Answer 2,550km

You now know the distance to the epicentre. Can you use this to find its location? No. It could lie anywhere on a circle of that radius centred on your school

Students will have to get information from at least two other places and use this to calculate their distance from the epicentre. They then use compasses to draw circles that should intersect close to the epicentre.

You quickly call your cousin's school in Auckland New Zealand 5,360km to your east. They estimated that the epicentre was 3,500 km away.

Can you now locate the epicentre with these two pieces of information? Explain your answer.
Information from two places would give two circles that would intersect in two places. We need a third location to find which one of these is the epicentre.

As luck would have it your adventurous aunt was doing scientific research on the Malaysian Peninsula 4,000 km to your north. Data from her seismometer inferred that the epicentre was 2,500km away.

Draw up you data with your cousin's data and your aunt's data to infer where the epicentre is.

Why do the arcs not intersect at exactly the same spot?
The map in the atlas is a flat projection of a curved surface. This distorts distance.

Only some of the seismic waves caused ripples in your aunt's flask. Explain why?
S waves do not trave through liquids and would not cause ripples.

Locating an Earthquake – Student Activities

Being human we tend to think of an earthquake only as it affects us on the surface of the Earth. The earthquake however starts at the **FOCUS** within the Earth. The spot on the Earth's surface closest to the focus is called the **EPICENTRE.** Draw a simple labelled diagram of this below.

Humans only usually feel earthquakes registering above magnitude 3. Other animals and birds are more sensitive and will display changed behaviour because they can feel early tremors.
Australia lies well away from its plate boundary but we still register seismic movement as our plate adjusts to external seismic movement.

The cliffs behind collapsed into the Redcliffs school's back yard during the 2011 Christchurch earthquake. Rock rolled and crashed right up to the back door. There was no damage to the fabric of the school and nobody was at school at the time

What are your school's rules about safety during earthquakes? _____

_____

_____

_____

How much time do you have to reach the safe assembly point after feeling the first P waves arrive?

_____

Seismic scenario

We know

1. P waves are the fastest waves to arrive. Their average speed is 7km/s.
2. S waves arrive next. Their average speed is 4km/s.
3. Very destructive surface waves may arrive later.

Locating an Earthquake – Student Activities

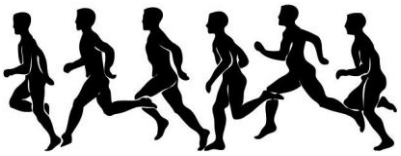
Materials per student

- An atlas
- A pencil (Not 2B)
- A ruler
- A pair of compasses
- A calculator
- An eraser
- Scrap paper

An earthquake is triggered at a plate boundary near Indonesia 3,500km away.

How long will it take for the P wave to reach your school? _____

How long will it take for the S wave to reach your school _____



Being a sensible science student you know that you should evacuate before the S wave arrives.

How much time do you have to get from the classroom to the evacuation point before the S wave hits? Use the space below for your calculations

_____

How long would it take you to get safely to your assembly point? _____

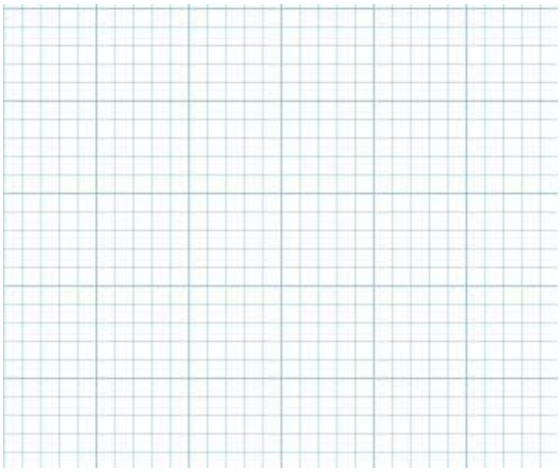
If you do not have sufficient time to get out of the classroom, what should you do to remain as safe as possible?

1. _____
2. _____
3. _____
4. _____
5. _____

The distance from an earthquake's epicentre can be roughly inferred by the interval in time between the arrival of P waves and S waves.

Interval in minutes	Distance in kilometres
1.5	900
3	1,800
5	3,300

Locating an Earthquake – Student Activities



An earthquake was registered on your school's seismograph. The interval between P and S wave arrivals was 4 minutes. Estimate the distance to the epicentre using the information in the table and the graph paper provided.

What kind of graph should this be? _____

What should be on the horizontal axis? _____

What should be on the vertical axis?_____

What should the title be?

_____

Distance to epicentre _____

You now know the distance to the epicentre. Can you use this to find its location? _____

_____

You quickly call your cousin's school in Auckland New Zealand 5,360km to your east. They estimated that the epicentre was 3,500 km away from them.

Can you now locate the epicentre with these two pieces of information? Explain your answer.

_____

As luck would have it your adventurous aunt was doing scientific research on the Malaysian Peninsula 4,000 km to your north. Data from her seismometer inferred that the epicentre was 2,500km away.

Draw up you data with your cousin's data and your aunt's data to infer where the epicentre is.

Why do the arcs not intersect at exactly the same spot? _____

_____

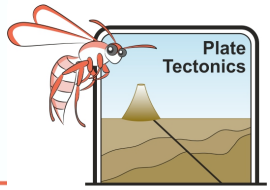
Only some of the seismic waves caused ripples in your aunt's flask. Explain why?

_____

Have you ever experienced an earthquake? _____

What did it feel like? _____

Seismic Waves - Review (Teacher)



S	F	O	C	U	S	Y	R	A	E	H	S	D	T	E
N	E	W	N	O	I	T	C	A	F	E	U	Q	I	L
O	P	K	I	N	H	G	Y	W	M	Q	N	K	D	U
I	I	H	A	G	S	K	S	A	A	O	H	E	I	C
S	C	L	I	U	N	U	G	E	I	V	S	L	U	E
S	E	L	L	I	Q	N	B	T	I	S	E	A	Q	L
E	N	R	L	O	I	H	C	D	U	S	G	S	I	O
R	T	S	M	T	R	U	T	R	U	E	M	T	L	M
P	R	K	U	Y	R	E	F	R	A	C	T	I	O	N
M	E	D	B	T	T	A	V	Q	A	K	T	C	C	E
O	E	O	S	Q	C	E	A	I	D	E	M	I	S	S
C	D	E	A	E	R	E	F	S	N	A	R	T	O	O
Y	D	Y	G	R	E	N	E	A	M	O	O	B	L	N
E	V	A	C	U	A	T	E	X	S	Q	N	M	I	I
T	R	E	M	O	R	C	J	I	N	D	E	X	D	C

BODY
BOOM
COMPRESSION
DESTRUCTION
EARTHQUAKES
ELASTIC
ENERGY
EPICENTRE
EVACUATE
FOCUS
GAS
INDEX
LIGHT
LIQUEFACTION
LIQUID
MAGNITUDE
MEDIA
MOLECULE
REFRACTION
ROLL
SAFETY
SEISMIC
SHEAR
SLINKY
SOLID
SONIC
SUBDUCTION
SURFACE
TRANSFER
TREMOR
WAVE

Seismic waves are energy waves released during earthquakes.

There are two kinds of seismic waves, body waves and surface waves

Name	Type of wave	Passes through	Speed	Most destructive?
P	Body	Solids, liquids & gasses	Fastest	
S	Body	Solids	Slower	
L&R (Love & Rayleigh)	Surface	Solids	Slowest	Most destructive

Seismic Waves - Review (Student)

Find the words listed below in the following word sleuth:

S	F	O	C	U	S	Y	R	A	E	H	S	D	T	E
N	E	W	N	O	I	T	C	A	F	E	U	Q	I	L
O	P	K	I	N	H	G	Y	W	M	Q	N	K	D	U
I	I	H	A	G	S	K	S	A	A	O	H	E	I	C
S	C	L	I	U	N	U	G	E	I	V	S	L	U	E
S	E	L	L	I	Q	N	B	T	I	S	E	A	Q	L
E	N	R	L	O	I	H	C	D	U	S	G	S	I	O
R	T	S	M	T	R	U	T	R	U	E	M	T	L	M
P	R	K	U	Y	R	E	F	R	A	C	T	I	O	N
M	E	D	B	T	T	A	V	Q	A	K	T	C	C	E
O	E	O	S	Q	C	E	A	I	D	E	M	I	S	S
C	D	E	A	E	R	E	F	S	N	A	R	T	O	O
Y	D	Y	G	R	E	N	E	A	M	O	O	B	L	N
E	V	A	C	U	A	T	E	X	S	Q	N	M	I	I
T	R	E	M	O	R	C	J	I	N	D	E	X	D	C

BODY
BOOM
COMPRESSION
DESTRUCTION
EARTHQUAKES
ELASTIC
ENERGY
EPICENTRE
EVACUATE
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ROLL
SAFETY
SEISMIC
SHEAR
SLINKY
SOLID
SONIC
SUBDUCTION
SURFACE
TRANSFER
TREMOR
WAVE

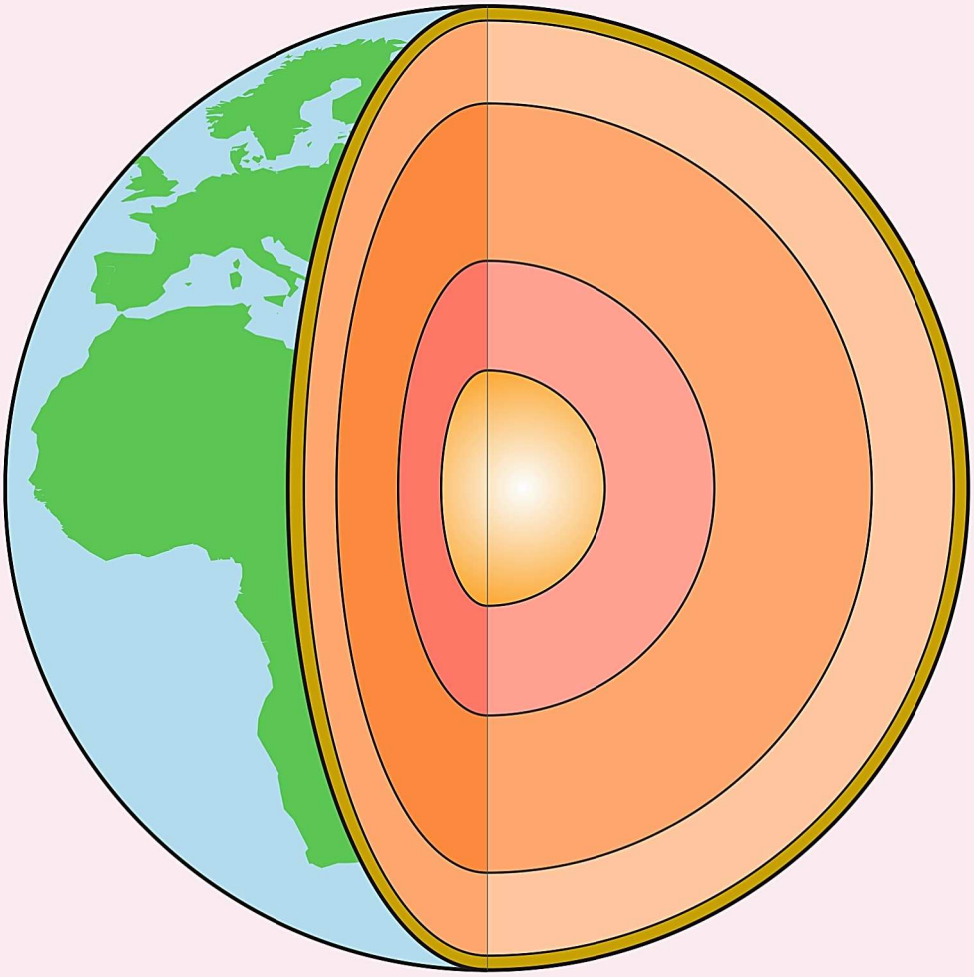
Seismic waves are _____.

There are two kinds of seismic waves _____.

Name	Type of wave	Passes through	Speed	Most destructive?
P				
S				
L&R (Love & Rayleigh)				

An initiative supported by Woodside and ESWA

Great Iron Catastrophe (GIC) and Planetary Differentiation



Primary and secondary data

Data is anything that is observable, measurable and repeatable. Primary data is data collected directly by the observer for a particular purpose. Secondary data has been collected by another observer for a similar reason and reused by a later scientist.

Background to early ideas on the structure of the Earth

In 276Bc Eratosthenese, an Ancient Greek scientist, fairly accurately estimated the circumference of Earth. He noted that at midday in mid summer the overhead sun shone directly down a deep well in the town of Alexandria, which lies on the Tropic of Cancer. He knew however that if he tried to do the same thing in his hometown of Syene further south, sunlight would be blocked by the shadow of his body. Erastosthenese realised that the surface of the Earth must be curved and that the Earth was a sphere. He calculated the elevation of the Sun using the gnomon from a sundial. As a result of measurements made during surveying trips he also knew the distance between the two towns. He concluded that if the Earth was a sphere the arc between the two wells was 1/50th of its circumference. This information was used by later scientists to calculate the volume of the Earth.

In 1687 Newton published his great "Principia Mathematica" which used mathematics and astronomical observations of his own on and of earlier scientists like Eratosthenese to explain planetary movement, size, density e and position. It was truly ground breaking science.

Edmund Halley the astronomer looked at one small section of Book 3 which estimated the relative masses of the Earth and Moon. Newton had miscalculated stating their relative masses were 1 to 26 making their relative densities 9 to 5. Newton made this estimation by observing the effect of the Sun and Moon on our tides. (Gravitational pull from the Sun and Moon affect water level). The moon's density was incorrect by a factor of three.

Halley proposed "Sir Isaac Newton has demonstrated the moon to be more solid than our Earth, as 9 to 5; why may we not suppose four ninths of our globe to be a cavity?" Haley also proposed that between the three hollow spheres was atmosphere and that the Aurora Borealis was escaping gas from within the hollow Earth. Halley had read accounts of caverns, cave systems and disappearing rivers in karst (limestone) country and many ancient stories of people living underground. He also tried to explain the wandering of the magnetic pole by proposing each shell had its own poles and would rotate at different speeds.

Robert Hooke, the Curator of Experiments for the Royal Society of London and others had already proposed that Earth was composed of spheres but did not suggest that there was space between the shells.

In due course the mathematical mistake was corrected and the idea of a hollow earth fell out of favour.

In the table below enter examples of primary and secondary data used by some of these scientists

Primary data

Scientist	Example of Primary data
Eratosthenes	He measured the elevation of the Sun
Eratosthenes	He measured the distance from Syene to Alexandria
Newton	He made astronomical measurements
Newton	He measured the effect of the Moon on tides on Earth
Halley	In this case he did not use primary data

Secondary data

Scientist	Example of Secondary data
Newton	He used data from earlier astronomers
Newton	He used data on the circumference of the Earth from Eratosthenes
Halley	He used data from a book
Halley	He used information from stories

Get together with another student and "Think, Pair, Share". What are the advantages and disadvantages of using primary and secondary data?
Share your findings with the rest of the class

Data type	Advantages	Disadvantages
Primary	Scientist selects samples to suit their research area Scientist can control choice of equipment to provide precision and accuracy Scientists can be confident of their own data	Takes time Expensive Personal prejudice might affect sourcing
Secondary	Cheaper Faster Less likelihood of personal prejudice affecting sample choice Wider sample choices may uncover new factors which could influence research	May not quite suit the research project Little control over accuracy or precision

From data we may make inferences. Inferences are themselves not facts. They try to logically explain why something may have happened.
Our grandparents thought we "caught a cold" by sitting in a cold place. We now understand that colds are the result of bacterial infection. Poor nutrition during winter caused a reduction of efficiency in our immune systems. Opportunistic germs could more easily attack.

As more data is collected (we can catch the cold at any season) and as improved technology is employed (microscopes show us bacteria and electron microscopes show us viruses), inferences may change.

An example of using primary and secondary data for economic advantage

Having people trained to understand earth processes is very important for Western Australia, a state dependant on resource industries for a lot of its income.

In Western Australia rock has been weathered and eroded for millions of years and mineral deposits lie obscured by tens or hundreds of meters of overburden.
Government and industry geologists created geological maps that extend known outcrops to connect with others of the same kind using structural and mineralogical evidence collected in the field.
Mineral exploration geologists then select areas where deposits might be found by studying these geological maps and comparing them with maps from areas of known mineralization elsewhere.

Geophysical surveys are then flown over prospects. Geophysical techniques can penetrate deep into the ground. Gravity and seismic surveys may indicate denser areas of differing rocks and structures, magnetic surveys may indicate metal deposits and radiometric surveys indicate the presence of radioactive minerals.
Interpretation of magnetic surveys result in finding large mineral deposits such as Telfer gold deposit and interpretation of the results for seismic surveys are essential in discovering and developing oil and gas fields.
Use this information to complete the table below

Primary data	Secondary data	Inference
Known geological outcrops	Areas mapped by other people	The area is/is not worthy of further exploration
Data from magnetic surveys	Surveys done elsewhere	The area is/is not prospective for magnetic minerals
Gravity surveys	Established geological data	Useful structures may be present
Seismic data	Other geophysical surveys	Mineralised rocks may/may not be present Structure to trap oil and gas may be present
Radiometric surveys		Radioactive minerals may/may not be present

Of course our views are coloured by those of previous generations. Later generations may have more data from advanced technology and these ideas will change. Shales, which were passed over during early oil and gas exploration phases, are now being explored for new oil and gas deposits.

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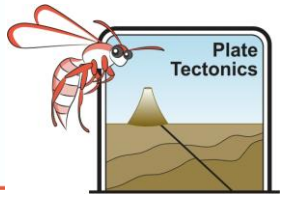

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Primary data

Scientist	Example of Primary data
Eratosthenes	
Eratosthenes	
Newton	
Newton	
Halley	

Secondary data

Scientist	Example of Secondary data
Newton	
Newton	
Halley	
Halley	

Get together with another student and "Think, Pair, Share". What are the advantages and disadvantages of using primary and secondary data?
Share your findings with the rest of the class

Data type	Advantages	Disadvantages
Primary		
Secondary		

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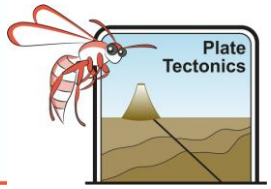
Of course our views are coloured by those of previous generations. Later generations may have more data from advanced technology and these ideas will change. Shales, which were passed over during early oil and gas exploration phases are now being explored for new oil and gas deposits.

Planetary Differentiation – Teacher Notes



Planetary differentiation - A theory supported by scientific data

DEFINITION A scientific theory is an hypothesis supported by data.

Data must be:

OBSERVABLE (5 senses)
MEASURABLE (SI – International units)
and **REPEATABLE**
before it is **REPORTABLE** (as Scientific data)

We will be dealing with mixtures and compounds. What is the difference between a mixture and a compound?

A ***mixture*** **A mixture contains two or more substances physically combined (can be separated by physical means)**

A ***compound*** **A compound contains two or more substances chemically combined (cannot be separated by physical means).**

Our planet has an atmosphere, a hydrosphere, a biosphere and a lithosphere. Is our planet a mixture or a compound? Explain your answer.
Our planet contains both mixtures and compounds. E.g. air (atmosphere) is a mixture of gasses, water (hydrosphere) has the compound di-hydrogen oxide H_2O, soils (biosphere) contain a mixture of minerals, water and living things (compounds) and rocks can be both mixtures and compounds.

Early scientists realised that rocks below the Earth's surface must be denser than those forming the crust because the estimated density of the planet as a whole was 5.52g/cm^3. This was very much larger than most rocks found on its surface (2.67g/cm^3 on average).

Worksheets on 'Hollow Earth' and 'Rock Density' in this package also cover these concepts.

Scientists hypothesised that:

1. During the first 300 million years the planet was much hotter than it is at present and rocks would be molten allowing minerals to be mobile.

2. Gasses would be driven upwards to form our atmosphere.

3. Denser materials would be pulled by gravity towards the center of the Earth.

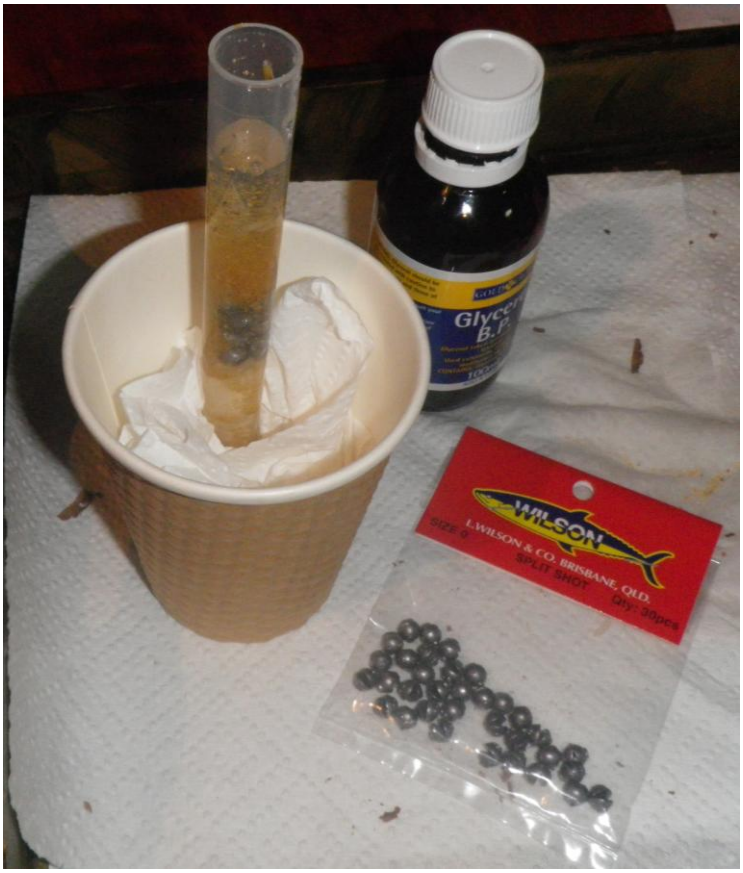
4. Five layers characterised by minerals of increasing density would be created (inner core, outer core, lower mantle, asthenosphere and crust.)

Students may have learned about the layers of the Earth, earthquakes and volcanoes in Primary School

Gravity separation of solids of different densities - Teacher demonstration

Materials

- One large measuring cylinder or test tube
- Sufficient water to 2/3 fill the container
- A teaspoonful, or prepared equal volumes of clean dry sand, iron or copper filings and lead shot.
- Teaspoon or spatula
- Stop watch or equivalent
- Graph paper, pencil and ruler



Rapid gravity separation can be demonstrated by dropping a mixture of clean washed sand, metal filings and lead shot into a column of transparent viscous fluid such as glycerol ($C_3H_8O_3$). (Glycerol is a mild laxative).
The viscosity of glycerol slows downward movement of solids enabling students to see and later measure their relative speeds.
A large volume of glycerol is necessary to fill a measuring cylinder and be visible to the class. The longer the cylinder, the better it is to separate out different densities and form obvious layers on the bottom of the cylinder.
Glycerol can be recovered after the experiment by filtration and re-used.
Water can also be used but descent is rapid and the times for different components difficult to measure.
Swarf or cotton wool at the bottom of the cylinder will reduce the chance of a Pyrex or glass cylinder breaking.
Lead shot is cheaply available from fishing shops or get lead from motor mechanics who use it to balance wheels. Copper pieces can be snipped from electrical cable.

The density of gold is included so that students may infer its behaviour from the other measurements given. Geologists suggest that gold is found in the Earth's core. Most gold deposits at the surface originate from a time when the Earth was markedly hotter and convection currents and plumes were able to flow from the core to the crust.

Were you able to collect scientific data from the teacher demonstration to support the hypothesis that planetary differentiation may depend on density differences? Explain your answer. No. Although the result was observable it was not measured or repeated.

Planetary Differentiation – Teacher Notes

AIM **To collect scientific data to support the hypothesis that planetary differentiation could be the result of density separation.**

Materials per student or group

- One measuring cylinder or large test tube
- Sufficient water to 2/3 fill the container
- A teaspoonful of prepared equal volumes of clean dry sand, iron/copper filings and lead shot or other solids
- Teaspoon or spatula
- Stop watch or equivalent
- Graph paper, pencil and ruler

You will be experimenting to see what happens when a mixture of solids falls through the column of water (or glycerol).

HYPOTHESIS (Make a scientific guess or estimate of what will happen when the mixture you have been given falls through the liquid).

The materials will be separated by their densities as they fall – or the reverse. (A negative hypothesis is as valid as a positive hypothesis)

METHOD

1. Gently sprinkle the mixture onto the top of the liquid in the test tube
2. Measure the time it takes for each component of the mixture to reach the bottom of the water.
3. Clean your equipment as directed by your teacher and repeat your measurements twice more.

Your teacher will tell you the density of the components after you have collected your data. This is primary data (data you have collected yourself).

Observations

Component	Time taken to reach bottom (seconds)				Density of component (g/cm^3)
	First test	Second test	Third test	Average	
Sand (dry)					**1.62**
Iron					**6.98**
Nickel					**8.91**
Lead					**11.34**
Gold	No data	No data	No data	No data	**19.30**

Water has a density of $1g/cm^3$

Planetary Differentiation – Teacher Notes

Why did we require three tests? **To achieve accuracy**

What did you observe? **Lead fell fastest followed by iron and lastly sand. The materials separated into layers of different density into at bottom of cylinder**

Did the data support your hypothesis? **Yes or No (depends on hypothesis)**

How could this experiment be improved to provide better data? **Repeat – longer tube & more viscous liquid to separate densities – different materials**

What force caused the mixture to move to the bottom of the container? **Gravity**

Write the density of each component into the final column.

Draw a graph comparing the density of the component with the speed it took to reach the bottom.

HINTS

1. What should the title of the graph be? **A comparison of X and Y**
2. What should the X-axis be? **Time (seconds)**
3. What should the Y-axis be? **Density (g/cm^3)**
4. What type of graph should it be? **Line graph**

Is there a correspondence between density and rate of falling (gravitational pull)? **Yes**

An inference is a judgement made from the evidence provided.

Can you infer what time it would take for the gold to reach the bottom? **Yes.**

This process is used in mining to separate denser minerals from crushed rock. Gemstones can also be classified by dropping them into viscous liquids. The rate of movement through the liquid reflects the density and chemistry of the stone.

Conclusion

How does this experiment help to explain how early Earth became layered into crust, mantle and core?

Residual heat created molten rock that allowed materials to separate according to their densities.

Did the experiment prove this idea/hypothesis?

No. It only supported the hypothesis. Nothing is "proven " in Science. If new technologies produce different more accurate results we must be willing to change our ideas.

Some scientists call this movement of iron towards the core "The GREAT IRON CATASTROPHE" or "THE GREAT IRON EVENT". Early Earth was hotter because heat energy came from both gravitation collapse of planetary dust (heat of formation) and from radioactive decay. Of course once the heat of formation was radiated into space it became cooler and there was less movement of molten materials.

Extension Homework (for patient persistent students)

Movement of materials of different densities in liquids is fast. Geological processes however are slower.
This activity may take several days to produce data that is observable, measurable and repeatable. You will need to test locally available materials, as the results will vary with acidity of jelly crystals, strength of jelly formed, local temperature and size of iron filings.

AIM **To see if iron filings will move through a jelly**

Materials

- 1 packet or jelly crystals
- 400mL hot water
- 2 beakers
- Metal filings (about 4 tablespoons)

Method

1. Mix jelly and water and divide into 2 beakers (one control and one experimental beaker) and leave to partially set (about 1 hour).
2. Heap the iron filings on the top of one beaker of set jelly.
3. Leave until fully set and observe.

Molten rock is extremely slow moving unlike liquid jelly or glycerine. Surface tension delays movement and plumes of iron form moving down to the base of the beaker. When the magnetic core of the Earth was established this process would speed up due to magnetic attraction. This can be demonstrated by placing a bar magnet under the beaker. The jelly becomes rapidly shredded and iron forms a lower layer.
If the jelly has a high percentage of food acid, di-hydrogen sulphide gas bubbles (rotten egg gas) may form at the side of the iron filings.
If the jelly is too firm the tongue of descending iron will not develop.

Planetary Differentiation – Student Activities

Planetary differentiation - A theory supported by scientific data

DEFINITION A scientific theory is an hypothesis supported by data.

Data must be

O_____

M _____

and R _____

before it is R_____

We will be dealing with mixtures and compounds. What is the difference between a mixture and a compound?

A ***mixture*** is _____

_____

A ***compound*** is _____

_____

Our planet has an atmosphere, a hydrosphere, a biosphere and a lithosphere. Is our planet a mixture or a compound? Explain your answer.

_____

_____

_____

Early scientists realized that rocks below the Earth's surface must be denser because the estimated density of the planet was 5.52g/cm^3 this was very much larger than rocks found on its surface (2.67g/cm^3).

They hypothesised that:

1. During the first 300million years the planet was much hotter than it is at present and rocks would be molten
2. Gasses would be driven upwards to form our atmosphere
3. Denser materials would be pulled by gravity towards the center of the Earth

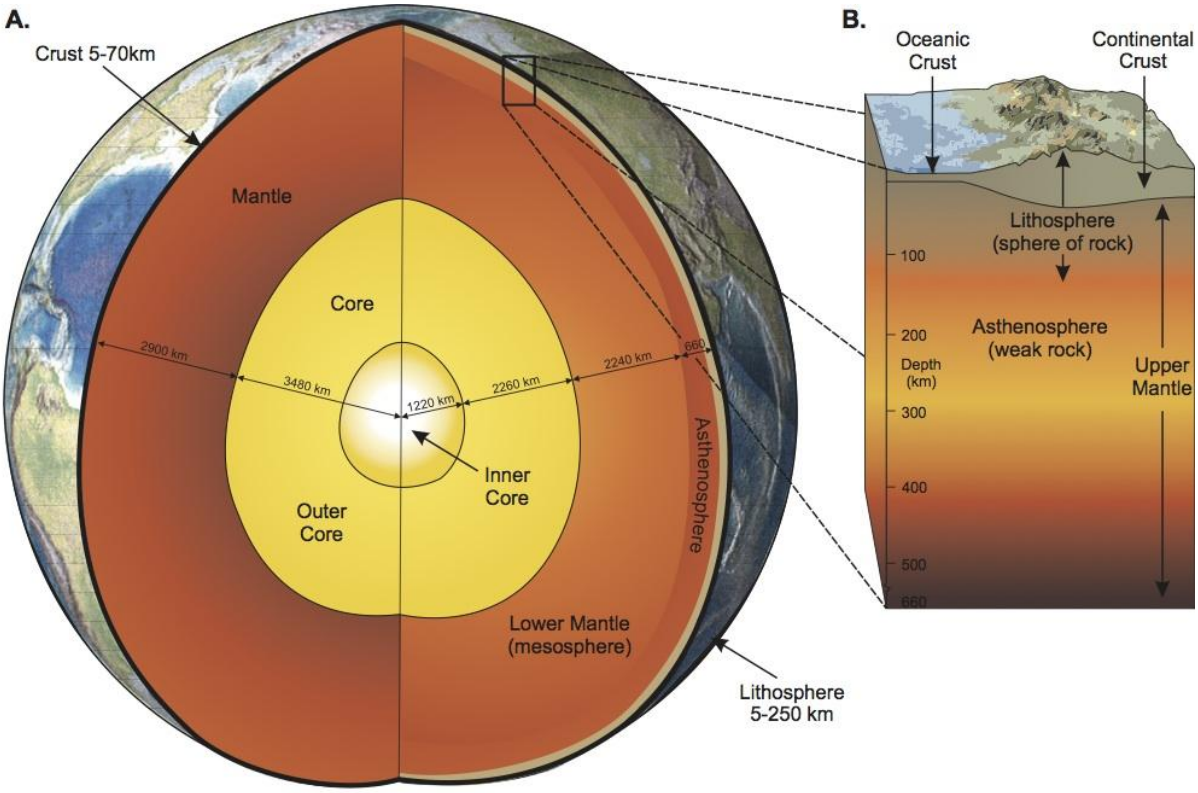
4. Five layers of increasing density would be created

We will be testing the hypothesis that planetary differentiation (core, mantle and crust) could result from density separation.

Your teacher will demonstrate an activity

Did this activity scientifically support the hypothesis that planetary differentiation is the result of density separation?

_____



Composition of the Earth (Tompkins, 2010)

You will now collect scientific data that is observable, measureable and repeatable.

<u>AIM</u> To collect scientific data to support the hypothesis that planetary differentiation could be the result of density separation in the early molten Earth.

Materials per student or group

- One measuring cylinder
- Sufficient water or glycerin to 2/3 fill the container
- A teaspoonful, or prepared equal volumes of clean dry sand, iron filings and lead shot or equivalent.
- Teaspoon or spatula

- Stop watch or equivalent
- Swarf or cotton wool
- Graph paper, pencil and ruler

You will be experimenting to see what happens when a mixture of sand, iron filings and lead shot falls through the column of water or glycerol. The solids represent minerals of different densities and the glycerine or water represents early molten Earth.

HYPOTHESIS: Make a scientific guess or estimate of what will happen when the mixture you have been given falls through the liquid.

_____

_____

METHOD:

1. Gently sprinkle the mixture onto the top of the liquid in the test tube
2. Measure the time it takes for each component of the mixture to reach the bottom of the water.
3. Clean your equipment as directed by your teacher and repeat your measurements twice more.

Your teacher will tell you the density of the components after you have collected your data. This is primary data (data you have collected yourself).

Observations

Component	Time taken to reach bottom (seconds)				Density of component (g/cm^3)
	First test	Second test	Third test	Average	
Gold	_____	_____	_____		19.30

Your teacher will inform you of the density of the materials you used.

Why did we require three tests? _____

What did you observe? _____

Did the data support your hypothesis? _____

_____

How could this experiment be improved to provide better data? _____

_____

_____

What force caused the mixture to move to the bottom of the container? _____

Write the density of each component into the final column

Draw a graph comparing the density of the component with the speed it took to reach the bottom.

HINTS

1. What should the title of the graph be?

   _____

2. What should the X-axis be labeled? …… in which units?

   _____

3. What should the Y-axis be labeled? …. in which units?

   _____

4. What type of graph should it be? _____

Using this data, is there a correspondence between density and rate of falling (gravitational pull)?

_____

An inference is a judgement made from the evidence provided. Can you infer the time it would take for gold to reach the bottom?

_____

Density separation is used in mining to separate denser minerals from crushed rock. Gemstones can also be classified by dropping them into viscous liquids. The rate of movement through the liquid reflects the density and chemistry of the gemstone.

Cubic zirconium is commonly cut to look like diamond. A simple test in liquid will prove which stone has been used

Conclusion

How does this experiment help to explain how early earth became layered into crust, mantle and core?

_____

_____

_____

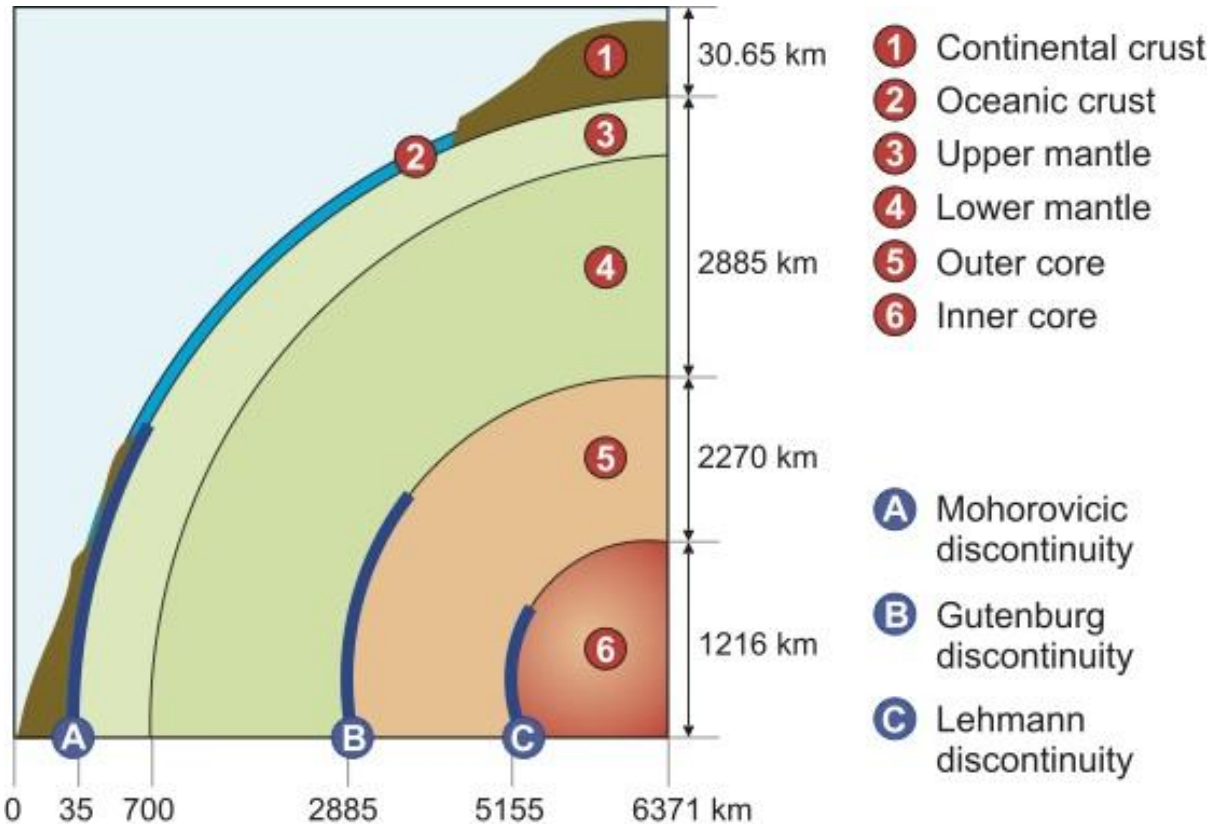
Did the experiment prove this hypothesis? _____

_____

Some scientists call this movement of iron towards the core "The GREAT IRON CATASTROPHE" or "THE GREAT IRON EVENT". Movement was restricted when heat from the original collapse of planetary dust to form Earth was lost into space.

GIC & Rock Density – Teacher Notes

After the first three billion years, it is thought that Planet Earth had differentiated into a nickel-iron core, a mantle and a silicate rich crust, by density sorting whilst it was mostly molten. The planet was hotter than at present because heat generated by gravitational collapse of the solar dust disc had not yet been radiated into space. Presently our planet is primarily heated by natural radioactive decay. The process of density sorting is called planetary differentiation or "**The Great Iron Catastrophe**". The word catastrophe is used in drama to describe the final scenes in an Ancient Greek play when everything is sorted out.



Schematic view of the Earth's interior (Tompkins, 2010)

The crust itself consists of two layers

1. **Continental crust** that has a low density and is mostly made of sedimentary rocks such as sandstone overlying silica rich (felsic) igneous rocks such as granite.
2. **Oceanic crust** which is denser and made of silica poor mafic igneous rocks such as basalt.

Hypothesis: Rocks from oceanic crust are denser than those from continental crust.

If we want to support this hypothesis with data we can easily access rocks of the continental crust under our feet. They are rich in silica and examples would be sediments such as sandstone, limestone and mudstone or silica rich igneous rocks such as granite and rhyolite. All continents and continental shelves are made of this material.

The continental crust "floats" on denser iron and magnesium rich oceanic crust. Specimens from oceanic crust however can only be collected when volcanism brings rocks such as basalts and

peridotites from oceanic crust and upper mantle to form islands or massive outpourings (flood basalts) during major tectonic events.

Rarely, when slabs of oceanic crust are thrust over continental crust, we can sample ophiolites. Slabs of ophiolites can be found in New Zealand and Tasmania.

Information from dense nickel iron meteorite fragments which may be from the core material of exploded planets, is also used as proxy evidence

In Year 8 students should have classified igneous rocks into less dense felsic (light in colour and silica rich) and mafic (dark in colour and magnesium rich) rocks.

Density averages for the spheres of our planet

Location on planet	Density (g/cm^3)
All Earth	5.45
Continental crust	2.7 – 3.0
Oceanic crust	3.0 – 3.3
Upper mantle	3.3 – 5.7 increasing with depth
Outer core	9.9 – 12.2
Inner core	12.6 – 13.0

Students will need a variety of continental crust specimens (sandstone, limestone, mudstone, coal and granite) to compare with specimens of oceanic crust (basalt, gabbro and peridotite). If the school does not have specimens then a table of densities of Western Australian rocks is attached

<u>AIM</u> To measure and compare the density of rocks from oceanic crust and continental crust

1. Discuss with your group and decide what equipment to order. Triple beam balances or equivalent, beakers or displacement cans, measuring cylinders. Size of each rock is a consideration when selecting beakers or cans. Perhaps calculators
2. Order the equipment necessary to estimate the mass, volume and therefore density of each rock. An order sheet is attached.
   (Ensure that this equipment will give readings to two decimal places)
3. Measure the mass and volume of each rock selected by your teacher
4. Enter the figures in the data sheet provided.
5. Calculate the density of each rock **(Mass ÷ Volume = Density)**

Materials

GIC & Rock Density – Teacher Notes

Observations

Rock	Mass (g)	Volume (cm^3)	Density g/cm^3
1			
2			
3			
4			
5			
6			

Conclusion

_____

_____

Discussion

Is this primary data or secondary data?

Primary data because I measured it myself for this specific purpose.

Using this data and the secondary data sheet below assign a location for the origin of each rock within the planet Earth.

Western Australian rock information

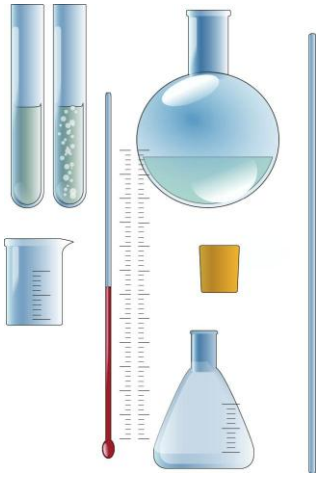
Rock Name	Possible source in WA	Density g/cm^3	Origin in planet
Basalt	Bunbury beach	3.00	Continental crust/Oceanic crust
Coal	Collie Mingenew	1.25	Continental crust
Diorite	Mt Bruce	2.95	Continental/upper oceanic crust
Dolomitic limestone	Hamersley Gorge	2.80	Continental crust
Gabbro	Windimurra	3.15	Oceanic crust
Gold	Kalgoorlie	19.32	Core
Lead ore (galena)	Northampton	6.23	Outer core
Gneiss	Dunsborough	2.82	Continental crust
Granite	Yilgarn	2.75	Continental crust

GIC & Rock Density – Teacher Notes

Limestone	Coastal WA	2.32	Continental crust
Marble		2.50	Continental crust
Mica schist	Bindoon	2.90	Continental crust
Nickel sulphides	Kambalda	8.13	Core
Peridotite	Argyle	3.40	Upper mantle
Quartzite	Jigalong	2.75	Continental crust
Rhyolite	Near Newman	2.55	Continental crust
Sandstone	Broome	2.55	Continental crust
Shale	Canning basin	2.45	Continental crust
Slate	Whim Creek	2.70	Continental crust
Student rock			
Student rock			
Student rock			
Student rock			

Why do most of our specimens come from continental crust? Land is mostly continental crust.

Laboratory equipment order sheet



Group names _____

_____

_____

_____

Room Number _____

Teacher _____

Date required _____

Materials requested Please give name of equipment and size

Date requested _____

An initiative supported by Woodside and ESWA

GIC & Rock Density – Teacher Notes

A simpler inexpensive version of the rock density experiment

For schools with limited equipment or with students who have problems calculating density this simpler experiment will allow for relative estimation of density of rocks.

A plastic coat hanger can be used as a beam balance to demonstrate the relative density difference.

Rocks selected need to be of about the same size.

Materials

- Plastic coat hanger
- String
- Assorted rocks

Alternatively a plastic shopping bag can be attached to each end of the coat hanger and used like balance pans to contain equal volumes of different rock specimens. This is easier if you are using broken pea gravel, pieces of concrete, calcrete or road metal.

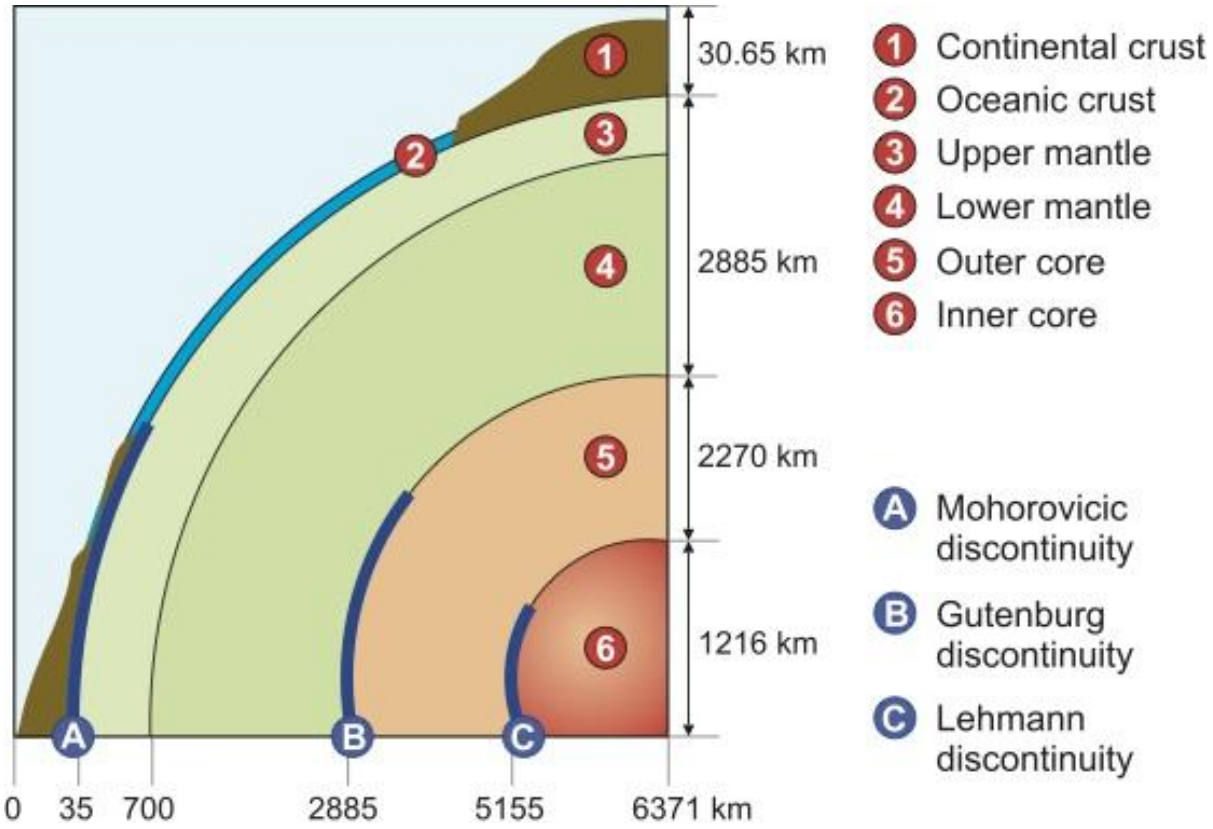
If you are using a wire coat hanger, wrap masking tape round the arms to form bumps to retain the string or plastic bag handles.

The rock on the right is dense iron rich basalt from the base of oceanic crust brought to the surface by a volcano in Iceland. The rock on the left is sandstone, a sedimentary rock, from continental crust near Geraldton WA.

Although you can gain an impression of how rock density ranges, the equipment does not provide a data which is accurate (true reading) and precise (to two decimal places).

GIC & Rock Density - Student Activities

After the first three billion years, it is thought that Earth had differentiated into a nickel-iron core, a mantle and a silicate rich crust by density sorting, whilst it was mostly molten. The process is called planetary differentiation or "The Great Iron Catastrophe".



Schematic view of the Earth's interior (Tompkins, 2010)

The crust itself consists of two layers

1. Continental crust that has a low density and is mostly made of sedimentary rocks such as sandstone and silica rich (felsic) igneous rocks such as granite.
2. Oceanic crust which is denser and made of silica poor mafic igneous rocks such as basalt.

Continental crust forms continents and their surrounding continental shelves. Continents "float" on underlying oceanic crust in the same way a block of wood floats on water. We can easily gain access to primary data on continental crust because it lies under our feet however we have to depend on volcanoes to bring up pieces of denser, darker oceanic crust.

Rock density - Secondary data sheet

Location	Density (g/cm^3)
Average for Earth	5.45
Continental crust	2.7 – 3.0
Oceanic crust	3.0 – 3.3
Upper mantle	3.3 – 5.7 increasing with depth
Outer core	9.9 – 12.2
Inner core	12.6 – 13.0

GIC & Rock Density - Student Activities

Your teacher will provide you with several rocks.

AIM **To measure and compare the density of rocks from oceanic crust and continental crust**

Method

1. Order the equipment necessary to estimate the mass, volume and therefore density of each rock. An order sheet is attached.
   (Ensure that this equipment will give readings to two decimal places)
2. Measure the mass and volume of each rock
3. Enter the figures in the data sheet provided.
4. Calculate the density of each rock ***(Mass ÷ Volume = Density)***
5. Remember to enter the correct units for mass, volume and density

Rock	Mass ( )	Volume ( )	Density
1			
2			
3			
4			
5			
6			

Is this primary data or secondary data? _____

Using this data and the secondary data sheet provided assign a reasonable location for the origin of each rock within the planet Earth.

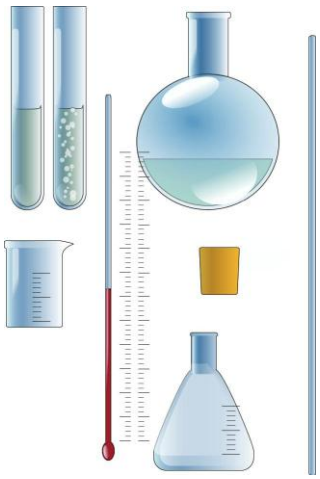
Western Australian rock information

Rock Name	Possible source in Western Australia	Density g/cm^3	Origin in planet
Basalt	Bunbury beach	2.90	
Coal	Collie Mingenew	1.25	
Diorite	Mt Bruce	2.95	
Dolomitic limestone	Hamersley Gorge	2.80	
Gabbro	Windimurra	3.15	
Gold	Kalgoorlie	19.32	
Lead ore (galena)	Northampton	6.23	
Gneiss	Dunsborough	2.82	
Granite	Yilgarn	2.75	
Limestone	Coastal WA	2.32	
Marble		2.50	

An initiative supported by Woodside and ESWA

Mica schist	Bindoon	2.90	
Nickel sulphides	Kambalda	8.13	
Peridotite	Argyle	3.40	
Quartzite	Jigalong	2.75	
Rhyolite	Newman	2.55	
Sandstone	Broome	2.55	
Shale	Canning basin	2.45	
Slate	Whim Creek	2.70	

Laboratory equipment Order sheet



Group names _____

_____

_____

_____

Room Number _____

Teacher _____

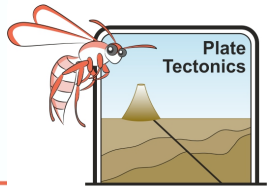
Date required _____

Materials requested

Please give name of equipment and size

Date requested _____

GIC - Review (Teacher)



W	E	U	E	N	B	E	Y	S	M	H	A	E	D	C
O	T	X	O	N	C	S	U	E	Y	N	S	G	N	R
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L	I	Y	F	L	P	R	O	L	N	L	R	O	O	S
O	G	R	P	O	O	T	E	E	I	E	A	P	P	T
H	U	R	R	N	H	R	H	C	H	C	L	H	M	G
S	E	T	E	E	O	T	A	P	Y	E	A	Y	O	E
J	J	A	S	A	S	T	S	T	A	L	D	S	C	O
O	K	I	T	O	T	D	W	D	I	T	G	I	Y	L
F	S	H	T	R	A	E	A	E	E	O	O	C	R	O
Y	R	A	D	N	O	C	E	S	N	N	N	S	O	G
P	R	I	M	A	R	Y	D	A	T	A	S	P	E	Y
E	C	A	T	A	S	T	R	O	P	H	E	I	H	Q
E	R	U	T	X	I	M	A	N	T	L	E	E	T	Y
P	L	A	N	E	T	I	C	L	E	K	C	I	N	Y

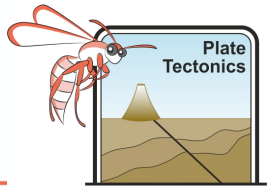
CATASTROPHE
COMPOUND
CRUST
DATA
DENSITY
EARTH
ERATOSTHENESE
EXPLORATION
GEOLOGY
GEOPHYSICS
GLYCERINE
GREAT
HALLEY
HEAT
HOLLOW
HYPOTHESIS
IRON
LEAD
MANTLE
MIXTURE
NEWTON
NICKEL
PLANET
PRIMARY
SECONDARY
SILICA
SPHERE
SUPPORT
SURFACE
THEORY

1. What is the difference between primary data and secondary data?
   Primary data is collected by a scientist themself for a specific purpose. Secondary data is collected for a similar purpose by someone else and reused by another.

2. What does “The Great Iron Catastrophe” refer to?
   The movement of iron and heavy metals towards Earth’s core very early in the planet’s history.

3. What is the difference between an hypothesis and a theory.
   An hypothesis is a scientific guess. A theory is an hypothesis supported by data.

GIC - Review (Student)



W	E	U	E	N	B	E	Y	S	M	H	A	E	D	C
O	T	X	O	N	C	S	U	E	Y	N	S	G	N	R
L	M	R	P	A	I	P	I	P	L	E	A	E	U	U
L	I	Y	F	L	P	R	O	L	N	L	R	O	O	S
O	G	R	P	O	O	T	E	E	I	E	A	P	P	T
H	U	R	R	N	H	R	H	C	H	C	L	H	M	G
S	E	T	E	E	O	T	A	P	Y	E	A	Y	O	E
J	J	A	S	A	S	T	S	T	A	L	D	S	C	O
O	K	I	T	O	T	D	W	D	I	T	G	I	Y	L
F	S	H	T	R	A	E	A	E	E	O	O	C	R	O
Y	R	A	D	N	O	C	E	S	N	N	N	S	O	G
P	R	I	M	A	R	Y	D	A	T	A	S	P	E	Y
E	C	A	T	A	S	T	R	O	P	H	E	I	H	Q
E	R	U	T	X	I	M	A	N	T	L	E	E	T	Y
P	L	A	N	E	T	I	C	L	E	K	C	I	N	Y

There are 30 words on this subject above. Write them below

1. What is the difference between primary data and secondary data?

   _____

   _____

2. What does “The Great Iron Catastrophe” refer to?

   _____

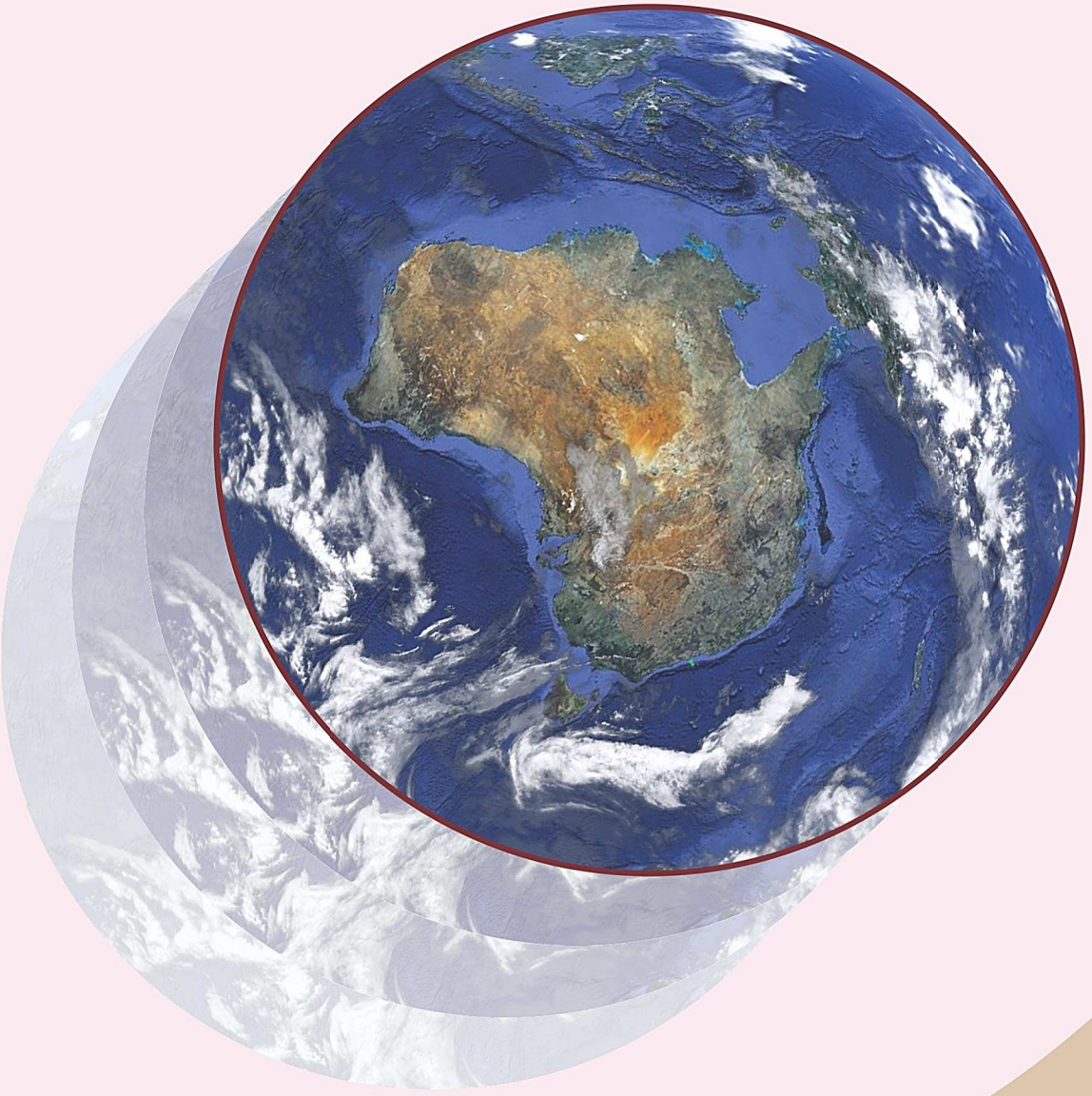
   _____

3. What is the difference between an hypothesis and a theory?

   _____

   _____

Can Humans Move the Earth?



Beaconsfield Disaster – Teacher Notes

Western Australia is our most seismically prone state. It also relies heavily on mining for income. Mining both causes and is affected by seismicity. Gold mineralisation often follows tectonic structures such as faults.
Miners tell of the rocks "talking" to them. Rock creaks, groans and spits as it adjusts to stress on mining cavity boundaries.
Incompetent (soft) rock such as that you find in coalmines makes constant small adjustments.
Competent "hard rock" found in some gold, silver and copper mines build up stress until it explodes with the sound of gunfire and earthquakes can be felt.
Dangers increase with depth.
Removing rock to form a cavity causes stress to the walls of adits, drives, shafts and stopes.
Broken wall and roof rock is usually supported by pit props, weld mesh, concrete and bolts to guard against collapse.
Controlled explosions (blasting) to break up rock will compound the pressure by overcoming limiting friction.

Pit props supporting a stope in the old Hannan's gold mine in Kalgoorlie

The deeper the mine the greater this pressure from overburden becomes. This increase may be demonstrated by cutting holes into a large clear plastic cool drink bottle and filling with water as demonstrated in the picture below.

*The **Pasca**l (Pa) is named after the French philosopher and scientist Blaise Pascal. It is a measurement of force per unit area. One Pa is the pressure one newton exerts on one square meter.*
Standard atmospheric pressure at the surface of the earth is 101325 Pa.
A mega Pascal MPa is 1,000,000Pa.
Pressure at the foot of a 3km mine can be 80Mpa (9x greater than at surface)
Pressure at the foot of a 4km mine can be 110MPa (108.6x greater than at surface)

Beaconsfield Disaster – Teacher Notes

When I was in my twenties working on the west coast of Tasmania, I accompanied an eighty-year-old miner exploring an adit (horizontal drive) in "hard rock" near Dundas. He had terrible rheumatism from years of hard physical work and only moved with difficulty. We were about a hundred metres from the mouth of the opening when the mine suddenly started "talking". The old miner was out and in the sunshine well before I realised what was happening and I had only just started after him as the adit started collapsing behind me!

The Beaconsfield Mining Disaster

The Tasmanian Beaconsfield goldmine collapse on the 25th April 2006 resulted in one death. Fourteen men working at 890m escaped after sheltering in safety chambers and two men spent fourteen days trapped in a small metal cage until they were rescued. Although the rock fall was originally reported as being due to an earthquake the Coroner's report suggests that the earthquake was the result of mining practices at that time.

http://www.magistratescourt.tas.gov.au/__data/assets/pdf_file/0005/120884/alx.016.002.0002_001.pdf

"As mining activity had progressed beyond a depth of 800m the pressure on the ore body in some locations commenced to exceed the inherent rock strength. In other areas of the mine, the removal of ore unclamped geological features…This caused an increase in seismic activity throughout the mine and also increased the number of rock falls, especially adjacent to firing times."

www.theage.com.au/flash/miners/rescue.htm provides a good introduction (but it does contain one expletive spoken by the rescued miner).

Materials per student or group

- Metre rulers or measuring tape (or the long edge of an A4 page is 30cm)
- Access to the Internet

Measure out a 1.2m X1.2m square on the ground. If possible add student backpacks to represent rocks. Fit two students into it and ask them how comfortable they would be if they had to spend twelve days trapped in that area.

Select at least two sources to ensure you have the most correct answer.

What problems would they have?
Muscle cramps, back pain and cuts, no light, no water, no food, cold, no waste product disposal, close contact, general frustration (including in this case differing football and car make allegiances).

Where is the Beaconsfield mine?
40kms north west of Launceston in Tasmania.

What did the earthquake measure?
2.1 on the Richter scale.

Did the earthquake itself trap the miners?
No the earthquake triggered a rock fall which trapped the miners.

How many miners were underground at the time?

Seventeen.
How many were trapped underground?
Three, one died.

Did the rescue party enter the mine immediately?
No they sent in a heavy loader with cameras first.

After they found the body of Larry Knight, what did the rescue miners intend to do?
They planned a horizontal tunnel towards where they thought the remaining two miners might be trapped in the rock fall.

What evidence did the rescuers have that two miners had survived?
They sound of their voices from a microphone that had been pushed into the area according to one source. Another source gave that two fellow miners breached safety protocol and crept in through dangerous passages. When they called out the trapped miners replied.

How had the miners avoided being crushed in the rock fall?
They had sheltered in a 1.2m X 1.2m cherry picker cage. Initially it was thought that they were protected by a large slab of rock above but the men said this was not so. The "ceiling" was made of many small rocks wedged together. They were partly buried by rocks and one had been knocked unconscious. They were able to free themselves by cutting through their trapped clothes and boots using Stanley knives.

How many days after the rock fall did food and water to the trapped miners?
Six. They shared one muesli bar in half to last for three days. One miner lost most of his half when it fell from his pocket as he slept.

How did the rescuers manage to get the food to the miners?
Through PVC pipe casing a drilled hole.

When the hole was expanded to 90mm what else was sent to the miners?
Vitamins, space blankets, fresh clothing, plastic bags and glo-sticks.

Why would the miners need plastic bags?
Waste (including human waste) disposal.

Finding drilling and blasting too dangerous, what novel technique do the rescuers decide to use?
A raise borer that literally grinds rock into powder

Did they start drilling the rescue bore immediately?
No they first drove a 16m pilot tunnel to initially break the rock, in much the same way that you drill a small hole in hard wood before expanding it.

Did they drive the pilot tunnel through to the miners?
No this would have been too dangerous. They realised that causing a cavity in the unconsolidated rock surrounding the miners might cause a collapse. They stopped before breaking through. They hoped to use jackhammers to penetrate the last part.

Why did the rate of penetration slow down again?
The rock is too hard (quartzite). One observer said that it was like trying to break steel with a paper

hankie!

What was the next technique the rescuers tried?
Low impact PCF explosives.

How long had the miners spent underground before the rescuers broke through?
Two weeks.

When did the two trapped miners walk into the light at last?
Tuesday May 9th

How was Science directly employed in the rescue?
The rescuers collected information from many sources across the world to plan their work
They regularly assessed the risks inherent with each new challenge.
As the situation changed they employed new technologies to overcome these problems.
The health of the men was monitored and food and support was changed as larger holes were created and their health needs changed.

Why do you think they sent iPods to the men?
The trapped miners' problems were not just physical but psychological also. The iPod would "isolate" them for a short while and provide entertainment suited to their own tastes.

What, to date is the longest time miners have been trapped underground and survived?
32 Chilean miners were trapped 688m underground for 69 days on the 5th August 2010

Lessons learned at Beaconsfield and the drilling expert from Beaconsfield were used to bring the miners to the surface in a rescue pod

If you were trapped underground in a confined space for two weeks what have you learned from this research that might help you during the ordeal? Is there anything else you recommend that might be of help?
Any reasoned response.

The 2010 Boulder Earthquake
On the 20th April 2010 an earthquake registering 5 on the Richter scale hit the Western Australian gold mining centres of Kalgoorlie and Boulder. Many of the older buildings in Boulder were damaged and local gold mines and the Mt Charlotte Super pit were closed. Kevin McCue the president of the Australian Earthquake Engineering Society suggested that the absence of aftershocks inferred the quake was caused by mining activities.

"Mining can be a dangerous occupation. Gold can be used to make jewellery. Underground gold mining should be banned in Australia because mining is dangerous and gold is used frivolously."

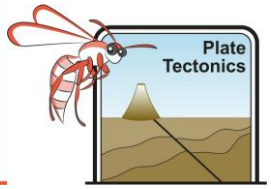
Consider these statements above and give a scientifically reasoned response to it below.
The worksheet suggests first establishing key words, Main ideas and writing a bibliography.

Visiting www.safeworkaustralia.gov.au/sites/swa/statistics/work-related-fatalities/pages/worker-fatalities may be of use.

Data/statistics show that working in the transport industry or even in Art and recreation is much more liable to kill you than mining.

Gold has many uses other than those that support vanity.

Beaconsfield Disaster – Student Activity



Western Australia is our most seismically prone state. It also relies heavily on mining for income.
Mining both causes and is affected by seismicity. Ancient faults caused pathways for underground fluids to bring up fluids with gold.
Miners tell of the mine "talking" to them. Rock creaks, groans and spits as it adjusts to stress on cavity boundaries.
Incompetent (soft) rock such as you find in coalmines makes constant small adjustments. Competent "hard rock" found in some gold, silver and copper mines build up stress until it explodes with the sound of gunfire and earthquakes can be felt.

The Beaconsfield Mining Disaster
The Tasmanian Beaconsfield goldmine collapse on the 25th April 2006 resulted in one death and two men spent fourteen days trapped in a metal cage until they were rescued.

You will be researching what happened during the two weeks when the miners were trapped.

First a visualisation tool for you (imagine):

Measure out a 1.2m X 1.2m area on the ground. Fit two large students into it. There is not enough headroom to sit up and the space is also full of rocks. How would you feel?

Remember to select at least two sources to ensure you have the most correct answer.

What problems would the miners have if they were confined for many days? _____

_____

_____

Where is the Beaconsfield mine? _____

What did the earthquake measure? _____

Did the earthquake itself trap the miners? _____

How many miners were underground at the time? _____

How many were trapped underground? _____

Did the rescue party enter the mine immediately? _____

_____

After they found the body of Larry Knight, what did the rescue miners intend to do? _____

_____

_____

Beaconsfield Disaster – Student Activity

What evidence did the rescuers have that two miners had survived? _____

_____

_____

How had the trapped miners avoided being crushed in the rockfall? _____

_____

_____

How many days after the rock fall did food and water to the trapped miners? _____

How did the rescuers manage to get the food to the miners? _____

When the hole was expanded to 90mm what else was sent to the miners? _____

_____

Why would the miners need plastic bags? _____

Finding drilling and blasting too dangerous, what novel technique do the rescuers decide to use?

_____

Did they start drilling the rescue bore immediately? _____

Did they drive the pilot tunnel through to the miners? _____

Why did the rate of penetration slow down again? _____

What was the next technique the rescuers tried? _____

How long had the miners spent underground before the rescuers broke through? _____

When did the two trapped miners walk into the light at last? _____

How was Science directly employed in the rescue? _____

_____

_____

Why do you think they send iPods to the men? _____

_____

_____

What, to date, is the longest time miners have been trapped underground and survived?

_____

Lessons learned at Beaconsfield and the drilling expert from Beaconsfield were used to bring these miners to the surface in a rescue pod

Please cite your references here:

_____

_____

_____

The 2010 Boulder Earthquake

On The 20th April 2010 an earthquake registering 5 on the Richter scale hit the Western Australian gold mining centres of Kalgoorlie and Boulder. Many of the older buildings in Boulder were damaged and local gold mines and the Mt Charlotte Super pit were closed. Kevin McCue the president of the Australian Earthquake Engineering Society suggested that the absence of aftershocks inferred the quake was caused by mining activities.

"Mining can be a dangerous occupation. Gold can be used to make jewellery. Gold mining should be banned in Australia because it is dangerous and is used frivolously."

Pit props used to support the roof of an old stope in Hannans gold mine in Kalgoorlie.

Beaconsfield Disaster – Student Activity

Consider these statements and give a scientifically reasoned response to them. Please cite references.

"Mining can be a dangerous occupation. Gold can be used to make jewellery. Gold mining should be banned in Australia because it is dangerous and is used frivolously."

Key words to use

Key ideas

Bibliography

Basel's Fault – Teacher Notes

During the natural breakdown of unstable radioactive elements within our planet, new elements are created and heat is the by-product. Rock, being a solid, holds this heat better than liquids or gasses.

The deeper you go the hotter it gets. At only five kilometres depth rock can be well over 40°C.

Groundwater (or meteoric water) can be held within pores and cracks in this rock. Hot water can be pumped from underground aquifers and used directly.

This ***passive geothermal energy*** is already used to heat water in swimming pools at Beatty Park and Bicton Baths in Perth. It can also be passed through heat inverters to supply energy for air conditioning as at the Chemistry Centre at Curtin University and at the University of Western Australia.

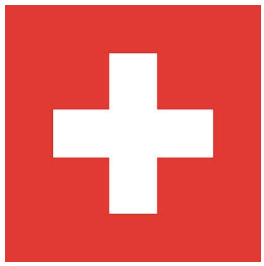
A three year program tapping into geothermal experts across the world finished in 2012. Perth has good supplies of water at about 230°C at depths of only 50 to 120 metres.

Tourists and local people enjoy hot water bubbling from underground at natural upwellings such as at Zebedee Springs near El Questro in the Kimberley. This use of geothermal energy causes minimal pollution and does not require the use of precious fossil fuels. Warm water also rises to the surface from underground pressure at the edge of artesian basins and along openings such as fault-lines.

Active geothermal energy can be obtained by pumping cold water from the surface down through drill holes into "hot rocks" such as granites at depths of up to five kilometres. Drilling costs limit depth. Water is the medium that carries heat back up to the surface to power turbines and create electricity for domestic and industrial use. (http://www.ga.gov.au/energy/geothermal-energy-resources.html)
Granite has a high thermal capacity (holds heat well) but is not permeable as it is crystalline. Drilling and fracturing (***stimulation or fracking***) creates small cracks that allow the cool water to pass down through the granite, be heated up and be pumped back to the surface. Sand is usually used as a proppant to hold the artificial pores open.

Rocks at depth are under stress from the burden of overlying strata and from tectonic plate movement. If they host pre-existing faults and are at sub-critical stress levels adding water can trigger a seismic event. Those wishing to undertake stimulation for geothermal energy must ensure that:

1. Geological and geophysical surveys have established if there are any major faults prior to drilling.
2. The history of seismicity of the area and present seismic data is available to establish the natural patterns of seismic background.
3. Using the data above, engineers establish "trip points" when it is considered that future stimulation should decrease or cease.
4. During stimulation surrounding holes are monitored for seismicity and fluid leakage
5. Safe engineering practices are followed including double casing and good well closure.



In cold countries with poor reserves of fossil fuel such as Switzerland, finding alternative energy sources is an economic necessity. Basel is major town in Switzerland that was trying to decrease its dependence on nuclear and fossil fuels. Nuclear energy was seen as a viable alternative until the Three Mile

Basel's Fault – Teacher Notes

Island incident, the Chernobyl incident and most recently the catastrophic result of a tsunami at Fukushima in Japan. Switzerland's nuclear power stations will have come to the end of their functioning lives by 2034. A program of drilling was established to tap into geothermal water from hot granites under a nearby valley.

Basel lies on a major fault and was almost destroyed by an earthquake in 1356. A major series of earthquakes were felt in Basel during stimulation of rocks to release geothermal energy. Stimulation ceased as a result of good engineering protocol and has not continued. The earthquakes however continued for some time.

Of course there are always conflicting opinions such as:

1. Without stimulation the earthquake would have happened anyway as the area has a history of instability.
2. The stimulation merely triggered faulting of pre-stressed rock and released a lesser earthquake before even greater stress had built up. The earthquakes would have happened anyway.
3. Stimulation should be required for faults near built up areas (such as the San Andreas Fault that is statistically overdue for a quake) before stress builds up. Many minor earthquakes are better than a major one.

Materials per student or group

- Access to Internet or a print of the article (Induced seismicity in Basel) at:

http://en.wikipedia.org/wiki/Induced_seismicity_in_Basel

Method

Read the article and answer the questions provided. Please explain your answers as in some cases more than one answer is possible.

Where was the geothermal project situated?

Basel is a large city in Switzerland.

(Switzerland is a small high country in the center of Europe. It has few fossil fuel energy sources of its own and relies on nuclear generated electricity and hydro-electric power supplemented by expensive oil imports from other countries. The last of its five nuclear power plants will be shut down in 2034 after parliament voted to wind down the countries' dependence on nuclear energy and seek alternatives)

What was the established problem?

Basel is built on a major fault.

How did the engineers know that there was an established problem?

The city was almost destroyed by an earthquake in 1356.

What was the trip point that caused the injection to be reduced?

Seismic events rising to Richter Magnitude ML 2.9

What was the trip point that caused the project to be suspended?

Seismic events reaching Richter Magnitude ML 4.4

Why were six borehole seismometers installed near the stimulation/injection well?

To monitor for any change in background seismicity

Basel's Fault – Teacher Notes

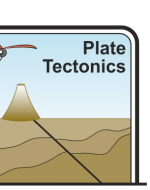
What was the damage claim by Swiss citizens as a result of the events?
7-9 million Swiss francs or 6.5 to 8.3 million US dollars

Why was the project cancelled?
It was considered too dangerous to continue

Has there been any direct benefit from this event?
The USA reacted to produce new regulations to govern deep geothermal energy projects

There are arguments for and against using geothermal power in Australia. List some of them and write your opinion below

Basel's Fault – Student Activity



Heat (geothermal energy) is generated by radioactive element breakdown deep within the planet. The deeper you go the hotter it gets.

Hot water can be pumped from underground aquifers and used directly.

Geothermal energy is already used to heat the swimming pools at Beatty Park and Bicton Baths in Perth. It is also used to supply energy for air conditioning at the Chemistry Centre at Curtin University and at the University of Western Australia.

This use of geothermal energy causes minimal pollution and does not require the use of precious fossil fuels.

Geothermal energy can also be obtained by pumping cold water from the surface down through drill holes into "hot rocks" such as granites at depths of up to five kilometers. Water is the medium that carries heat back up to the surface to power turbines and create electricity for domestic and industrial use.

Granite has a high thermal capacity (holds heat well) but is not permeable. It does not allow water to pass through it. Drilling and fracturing (***stimulation***) creates small cracks that allow the cool water to pass through the granite, be heated up and be pumped back to the surface.

Materials per student or group
Access to Internet or a print of the article (Induced seismicity in Basel) at:
http://en.wikipedia.org/wiki/Induced_seismicity_in_Basel

Read the article and answer the questions provided. Please explain your answers as in some cases more than one answer is possible.

In what city and in which country was the geothermal project situated?

_____

What was the established problem? _____

How did the engineers know that there was an established problem?

_____

_____

Had the engineers established a plan in case earthquakes were induced before they started drilling?

_____

_____

Basel's Fault – Student Activity

What was the trip point that caused the injection to be reduced? _____

_____

Why were six borehole seismometers installed near the stimulation/injection well?

_____

_____

What was the damage claim by Swiss citizens as a result of the events?

_____

Why was the project cancelled?

_____

Has there been any direct benefit from this event?

_____

_____

There are arguments for and against using geothermal power in Australia. List some of them and write your opinion below.

_____

_____

_____

_____

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_____

_____

Fracking Simulation – Teacher Notes

Following the decrease in conventional oil and gas production other techniques and other resources are necessary if we continue to support our present high levels of energy usage. We can use geothermal energy from underground by tapping into naturally hot rocks below us. We can also use different methods to release "tight" or "unconventional" oil and gas.

Stimulation and Fracking
A vertical hole is drilled down through the rock and then horizontal holes are drilled out from the base to penetrate surrounding rock. Water or other fluids is injected at great pressure to stimulate fracturing of the rock. Sometimes "proppants", which can be sand or man made ceramic materials, are injected with the water to hold the fractures open.

Stimulation for geothermal power production
In the Perth Basin we are fortunate to have hot water in our underground reservoirs that can be directly drilled to flow through drill holes to the surface. The water is heated by natural radioactive decay of minerals in granite. The source rock is porous and permeable allowing water to flow through it.
More information can be accessed at: http://www.greenrock.com.au/assetsWAPerthBasin.php

However in some places in the world cold water must be pumped down drill holes to be heated by naturally "hot" rocks before it can return to drive turbines. Water must be able to penetrate widely into the surrounding rock to heat up. Rocks such as granite and basalt are made of interlocking crystals, have no pores and must be artificially fractured to permit movement of fluid.

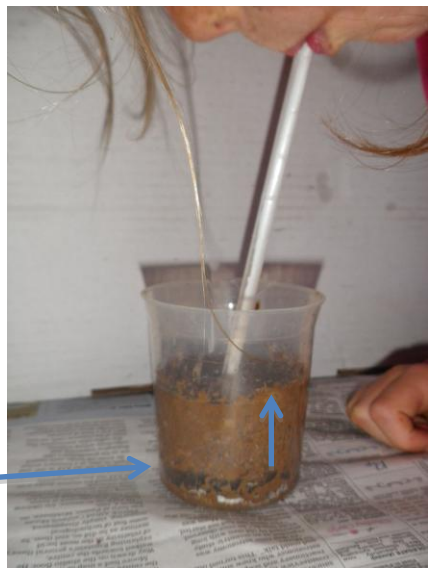
Stimulation for oil and gas production
Muds and silts compact and have very limited permeability. They produce shale and siltstone. Any contained oil or gas is tightly held and difficult to collect. We have vast reserves of this "tight" or "unconventional" oil and gas in our five great sedimentary basins.

To simulate the effect of introducing pressure in rock, students blow down straws that are set into firm, damp (***not wet)*** and compacted soils or sands. They may recall the effort it takes to dislodge a few centimeters of sand when they have buried their legs in wet at the beach.

NOTES

- If the sand/soil is too wet, it will splutter and students will suddenly develop freckled faces
- If the sand is too dry it will not appear to fracture but reassemble as grains separate.
- If the beaker is too full of soil students will be unable to blow hard enough to dislodge soil upwards.
- Students with breathing difficulties should be discouraged from blowing hard

Vertically dislodged soil



Fracking Simulation – Teacher Notes

AIM **To simulate fracking**

Materials per student or group

- Newspaper to protect bench or table
- Small beaker (200mL) or clear plastic drink cup
- Enough sand or soil to half fill the beaker/cup
- Water
- Plastic drinking straw
- Paper towel

Method

1. Cover the working surface with newspaper
2. Place the beaker in the centre of the paper
3. Hold the straw upright in the beaker with its end touching the base
4. Pack the soil/sand round the straw to a depth of about 3 cm
5. Add water to soil to dampen it. Keep adding water until no more can permeate the soil.
6. Gently tap the base of the beaker onto the paper to bring excess water to the surface
7. Mop up excess water with towel
8. Lift the straw until it lies just above the base of the beaker
9. Blow firmly down the straw.
10. Tamp down the soil and repeat

Observation

The soil/sand should rise as a mass and collapse. This simulates how pressuring rock can create fractures.

Points for consideration

1. Rock is stronger than damp sand because it has been compacted and cemented
2. Rock becomes increasingly pressurised at depth
3. Different rocks will react differently
4. Pressure from blowing is markedly less than produced during stimulation or fracking

Discussion

Why is stimulation or fracking used?
To create fractures in impermeable rock

What is injected into the rock at pressure?
Water and manmade ceramics

Name two different energy sources which may require use of fracking.
Geothermal power and hydrocarbon/oil and gas/tight gas/unconventional gas

We already use geothermal power in Perth to heat swimming pools, air condition buildings and create electricity. Did this require fracking?
No. The rock was already permeable.

What is meant by “tight” oil and gas?
Tight hydrocarbons are oil and gas reserves that are held in poorly permeable rocks.

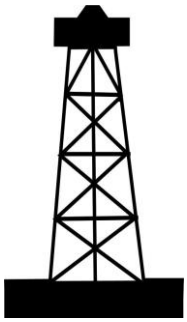
Why are we moving from conventional oil and gas as energy sources to “tight” hydrocarbons and

geothermal power?
We are using up conventional sources.

Interesting information - Western Australia has immense reserves of unconventional or tight oil and gas in five of our major sedimentary basins.

Fracking Simulation – Student Activity

As a result of a decrease in conventional oil and gas production other techniques and other resources are necessary if we continue to support our present high levels of energy usage. We can use geothermal energy from underground by tapping into naturally hot rocks below us. We can also use different methods to release "tight" or "unconventional" oil and gas. In both cases ***fracking, also called stimulation***, is used to increase the rate of fluid or gas movement within rock.



Stimulation and Fracking
A vertical hole is drilled down through the rock and then horizontal holes are drilled out from the base to penetrate surrounding rock. Water or other fluids are injected at great pressure to stimulate fracturing of the rock. Sometimes "proppants", which can be sand or man made ceramic materials, are injected with the water to hold the fractures open.

Stimulation for geothermal power production
In the Perth Basin we are fortunate to have hot water in our underground reservoirs that can be directly drilled to flow through drill holes to the surface. The water is heated by natural radioactive decay of minerals in granite.

Elsewhere, such as at Olympic Dam in South Australia, cold water must be pumped down drill holes to be heated by naturally "hot" rocks before it can return to drive turbines. Water must be able to penetrate widely into the surrounding rock to heat up. Rocks such as granite and basalt are made of interlocking crystals, have no pores and must be artificially fractured to permit movement of fluid.

Stimulation for oil and gas production
Muds and silts compact and have very limited permeability. They compact and are cemented to produce shale and siltstone. Any contained oil or gas is tightly held and difficult to collect. We have vast reserves of this "tight" or "unconventional" oil and gas in our five great sedimentary basins.

Aim **To simulate fracking**

Materials per student or group
- Newspaper to protect bench or table
- Small beaker (200mL) or clear plastic drink cup
- Enough sand or soil to half fill the beaker/cup
- Water
- Plastic drinking straw
- Paper towel

Method
1. Cover the working surface with newspaper
2. Place the beaker in the centre of the paper
3. Hold the straw upright in the beaker with its end touching the base
4. Pack the soil/sand round the straw to a depth of about 3 cm
5. Add water to soil to dampen it. Keep adding water until no more can permeate the soil
6. Gently tap the base of the beaker onto the paper to bring excess water to the surface

7. Mop up excess water with towel
8. Lift the straw about 25mm until it lies just above the base of the beaker
9. Blow firmly down the straw.
10. Tamp down the soil and repeat

Observation

_____

_____

_____

Conclusion (Did the activity simulate fracking?)

_____

Discussion

Why is stimulation or fracking used? _____

_____

_____

During fracking what is injected into the rock at pressure? _____

Name two different energy sources which may require use of fracking. _____

_____

We already use geothermal power in Perth to heat swimming pools, air condition buildings and create electricity. Did this require fracking? _____

What is meant by "tight" oil and gas? _____

Why are we moving from conventional oil and gas as energy sources to "tight" hydrocarbons and geothermal power?

_____

_____

Geothermal Stimulation & Porosity – Teacher Notes

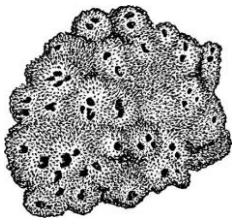
We can get heat energy from underground by tapping into natural hot water that lies within rocks below us or by introducing cold water into hot rocks and returning it to the surface to drive turbines that produce energy. To access the geothermal (geo = Earth, thermal = heat) heat in solid rock, water must be able to penetrate deep into the rock.

Similarly, to access oil and gas from reservoirs underground, the rocks must have pores or fractures which are joined to permit the hydrocarbons to move into the drill hole and be recovered.
http://www.geomore.com/porosity-and-permeability-2/

Porosity and permeability

Students should have encountered the terms ***porous*** and ***permeable*** in Earth Science in years 7 & 8.

Common student misconception
Many students believe that water and hydrocarbons lie in reservoirs which are fluid bodies sitting in enormous cavities underground. This is not so. The reservoirs are all the pores lying within rock joined together in a similar fashion to which water is retained within a sponge. Water and hydrocarbons can flow through the pores within the rock.



A ***porous*** rock has spaces between its grains. Sandstone and pumice are porous rocks.

A ***permeable*** rock has spaces that are joined up permitting movement of fluid and gas within the rock. Sandstone is permeable and makes a good reservoir for oil, gas and water. Pumice is not permeable as pores are not inter-connected.

An ***impermeable*** rock has no pores and can only be permeable if it has fractures. Granite and basalt are impermeable.

Teacher demonstration or student activity
Food cannot be eaten in a science room so this activity may have to be done elsewhere. This can be a memorable reward activity for good students. It is possible to buy packs of small Tim Tams and Aeros in supermarkets. Larger blocks can be cut with a knife.

The picture below is of sections through the biscuit and bar. Pores/spaces can be discerned in both but they are only joined in the Tim Tam.

What is meant by the porosity of a rock?
A porous rock has spaces between clasts or fractures within in it

Name a porous rock.
Sandstone, pumice, sandy limestone, siltstone (poor porosity)

What is meant by a permeable rock?
A rock where the pores or fractures are joined permitting liquids and gasses to pass through

Name a rock that is both porous and permeable.
Sandstone, sandy limestone

Why do you think that there is a picture of Tim Tams and an Aero bar above. (They will be asked this question again at the end of the activity).
Both show pores but the pores in the Aero are not connected. If we want to get hot water for geothermal power or hydrocarbons from underground, the rock must be permeable.

Materials

- One Aero chocolate bar
- One Tim Tam biscuit
- Milk or water in a glass

Tim Tam section above and Aero section below

Method

Tim Tam

Bite the ends (or opposing corners) from a Tim Tam. Hold it between your lips and suck air in. Does the Tim Tam let air (gas) pass through? Yes
Attempt to suck milk through it. (Use the Tim Tam as a straw). Does the liquid move through? Yes

Aero

Bite the ends off an Aero bar. Hold it between your lips and try to suck air in. Does the Aero let air (gas) pass through? No
Attempt to suck milk from the glass through the Aero. Does the liquid move through the bar? No.
Aero chocolate bars are full of large holes but the holes do not join up to permit movement within the bar. Aero bars are porous but not permeable

Which is porous, a Tim Tam or an Aero? Both have holes and are porous

Which is permeable, a Tim Tam or an Aero? Only the Tim Tam will permit liquids or gasses to travel through? Only the Tim Tam is permeable.

If you left a piece of Aero and a piece of Tim Tam in a glass of milk, which would soak up the most milk. Explain your answer. The Tim Tam would soak up most milk because its permeability would allow milk to soak through the whole biscuit. The aero would not allow penetration of milk.

Porosity and permeability are important to permit the movement of hydrocarbons (oil & gas) to reservoirs and the formation of groundwater reservoirs within rock. Revisit the first question and see if you can write a better answer using more technical language.
Porosity, permeability, rock, reservoir, liquid & gas.

Most of Western Australia's conventional oil and gas reservoirs are in permeable rocks such as sandstone. Since they are already under pressure from the mass of rock above they will rise to the surface if penetrated by a drill hole. Our much larger "tight " oil and gas supplies need stimulation or fracking. This is covered in "Stimulation/fracking activity" in this section

Geothermal Stimulation & Porosity – Student Activity

We can get heat energy from underground by tapping into natural hot water that lies in rocks below us or by introducing cold water into these hot rocks and returning it to the surface to drive turbines to produce electricity. Water will only move through ***permeable*** rock.

Porosity and permeability

What is meant by the porosity of rock? _____

_____

Name a porous rock _____

What is meant by a permeable rock? _____

_____

Name a rock that is both porous and permeable _____

Why do you think there is a picture of Tim Tams and an Aero bar below? _____

_____

Materials

- One Aero chocolate bar portion
- One Tim Tam biscuit
- Milk or water in a Petri dish or flat dish

Tim Tam

Bite the ends (or opposing corners) from a Tim Tam to remove the chocolate outer seal. Hold it between your lips and try and breathe through it. Does the Tim Tam let air (gas) pass through?

_____

Attempt to suck milk from the glass through it. (Use the Tim Tam as a straw). Does the liquid pass through the biscuit?

_____

Aero

Bite the ends off an Aero bar. Hold it between your lips and try and breathe through it. Does the Aero let air (gas) pass through?

_____

Attempt to suck milk from the glass through the Aero. Does the liquid move through?

_____

Section through Tim Tam above and Aero below

Which is porous, a Tim Tam or an Aero? _____

_____

Which is permeable, a Tim Tam or an Aero? _____

_____

If you left a piece of Aero and a piece of Tim Tam in a glass of milk, which would soak up the greatest volume of milk. Explain your answer.

_____

_____

_____

Geothermal Stimulation & Porosity – Student Activity

Porosity and permeability are important to permit movement of hydrocarbons (oil & gas) to reservoirs and the formation of underground water reservoirs within rock. Revisit the first question (copied below) and see if you can write an answer that relates the bar and the biscuit to obtaining geothermal power from rocks.

_____

_____

Create a Cavern – Teacher Notes

What created these interesting flat topped "hills" in Kalgoorlie?
These are ***spoil heaps*** left over from mining. Once the ore and mullock (non-economic country rock) is removed it is processed and the ore refined. The leavings are piled up as spoil.

Does the volume of the rock piles represent the amount of empty space mined out below?
The spoil heaps only represent the non-economic leavings of mining. The resource is removed and refined. However, there is no direct relationship between volume they take up above ground + resource and volume removed below. Above ground there are more voids left between rocks as they are piled up

Pit props in a stope in Hannan's Gold Mine, Kalgoorlie.

Removing rock to form a cavity causes stress to the walls of adits, drives, shafts and stopes. Broken wall and roof rock is usually supported by pit props, weld mesh, concrete and bolts to guard against collapse. The roof of the open stope created by gold mining at Hannan's Mine near Kalgoorlie is supported by pit props. The old props had to be replaced by fresh new ones when the mine was re-opened for tourists.

Rock and even unconsolidated soil and sand can support small cavities without collapsing.

<u>Aim</u> **To find if wet sand can maintain a cavity without collapsing.**

Students are asked to do a trial run before designing a proper experiment to see if the proximity of an earthquake will affect the ability of sand/soil to maintain a cavern.

Materials per group

- A large beaker (over 1000mL) bucket or container (See below for alternatives)
- Clean damp sand or soil
- 3 balloons
- A long skewer

Create a Cavern – Teacher Notes

Method

1. Inflate the balloons and tie them off. They should have different diameters but be small enough to fit easily inside your container with at least 3cm of sand piled on top.
2. Place a little sand on the bottom of the container, place the balloon on top and fill with sand until the balloon is covered with at least 3cm sand.
3. Tamp down the sand firmly.
4. Insert the skewer to deflate the balloon.
5. Observe and report what happens

This activity can alternatively be carried out in the school's sandpit, long jump or high jump pits or in the garden. Students will need trowels.

Results vary depending on the materials used. This activity is flawed as a scientific experiment as variables are not controlled. Students will be asked to design an improved version controlling variables and repeating any measurements.



Usually, the balloon deflates without the cavity collapsing.
Why did the sand not collapse when the balloon was punctured?
This is due in part to the small amount of pressure caused by overlying sand, partly to the adhesive nature of water and partly due to the curved shape left by the balloon.

Miners and architects learned from Nature that burrows with rounded roofs remained stronger longer than those with flat roofs and that arched roofs permitted wider cavities below. The compressional pressure is diverted from the roof to the walls. The deeper the mine the greater this pressure from overburden becomes.

A gold prospector's adit driven into greenstones near Yalgoo. Note escaping resident micro-bats .

Add more sand/soil until the cavern lid collapses.

Scientists often run a trial version of an experiment before they collect data.
Why would they do this?
To ensure equipment selected will work and they can collect data that is both precise (repeatable) and accurate (of a suitable scale).

Create a Cavern – Teacher Notes

The following activities can be done as extension or homework as they require minimal equipment.

Extension
Redesign this experiment to make it a "fair test".

What is your hypothesis? _____

What is the dependent variable? _____

What is the independent variable _____

Which variables have been controlled? _____

_____

How did you ensure your measurements were accurate? _____

_____

How did you ensure your measurements were precise? _____

_____

What data did you collect? _____

_____

What conclusions can you draw from the data? _____

_____

Extension - Pressure increases with depth.

Method

- Take an empty cool drink container and make three holes in a vertical line down its side.
- Fill a measuring jug or another empty bottle with water and go outside onto a grassed area.
- With the holes on the side of the bottle pointing away from your body, rapidly fill the bottle with water.
- Observe the waterspouts.

How can you tell that pressure increases with depth in this experiment?
Water near the top dribbles out whereas the water from the lower hole spouts out almost horizontal

Create a Cavern – Teacher Notes

Why do the waterspouts have different shapes?
The lower spout is pressurised by a higher column of water above it.

Is there any other data you could measure that would support the hypothesis that the lowest spout was under greatest pressure?
Measure the distance the spouts cover on a horizontal plane. Put your fingers in the waterspouts and feel (relative measurement) which felt strongest.

If you can access Youtube I can highly recommend watching National Geographic: Megastructures-Tau Tona – City Of Gold! (47m) to find all the pressure miners work under in one of the deepest mines in the world. http://www.youtube.com/watch?v=7MIrUZzFl2s

Interesting fact
The pascal (Pa) is named after the French philosopher and scientist Blaise Pascal. It is a measurement of force per unit area. One Pa is the pressure one newton exerts on one square meter.
Standard atmospheric pressure at the surface of the earth is 101325 Pa.
A megapascal MPa is 1,000,000Pa.
Pressure at the foot of a 3km mine can be 80Mpa (9x greater than at surface)
Pressure at the foot of a 4km mine can be 110MPa (108.6x greater than at surface)

Pumping water from underground
In California pumping underground water for domestic supplies and a decrease in rainfall has produced a lowering of the water table. The competency of the reservoir rock has decreased and many small earthquakes have been measured locally.

Create a Cavern – Student Activity

What created these interesting flat topped “hills” in Kalgoorlie? Please explain your answer.

_____

_____

_____

Does the volume of the rock piled at the surface represent the amount of empty space mined out below? Please explain your answer.

_____

_____

_____

Removing rock to form a cavity causes stress to the walls of adits, drives, shafts and stopes. Broken wall and roof rock is usually supported by pit props, weld mesh, concrete and bolts to guard against collapse.
The hanging wall (angled roof) of the open stope created by gold mining at Hannan’s Mine near Kalgoorlie is supported by pit props. The old props had to be replaced by fresh new ones when the mine was re-opened for tourists.

Rock and even unconsolidated soil and sand can support small cavities without collapsing.

An initiative supported by Woodside and ESWA

Create a Cavern – Student Activity

<u>AIM</u> **To find if wet sand can maintain a cavity without collapsing.**

Students are asked to do a trial run before designing a proper experiment to see if the proximity of an earthquake will affect the ability of sand/soil to maintain a cavern.

Materials per group

- A large beaker (over 1000mL) bucket or container (See below for alternatives)
- Clean damp sand or soil
- 3 balloons
- A long skewer

Method

1. Inflate the balloons and tie them off. They should have different diameters but be small enough to fit easily inside your container with at least 3cm of sand piled on top.
2. Place a little sand on the bottom of the container, place the balloon on top and fill with sand until the balloon is covered with at least 3cm sand.
3. Tamp down the sand firmly.
4. Insert the skewer to deflate the balloon.
5. Observe and report what happens



Why did the sand not collapse when the balloon was punctured? _____

_____

Add more sand/soil until the cavern lid collapses.

A gold prospector's adit driven into greenstones near Yalgoo. Note escaping resident micro-bats .

Miners and architects learned from Nature that burrows with rounded roofs remained stronger longer than those with flat roofs and that arched roofs permitted wider cavities below. The compressional pressure is diverted from the roof to the walls. The deeper the mine the greater this pressure from overburden becomes.

Create a Cavern – Student Activity

Scientists often run a trial version of an experiment before they collect data. Why would they do this?

_____

Extension - Adjust, adapt, improve

Redesign this experiment to make it a "fair test".

What is your hypothesis? _____

What is the dependent variable? _____

What is the independent variable _____

Which variables have been controlled? _____

_____

How did you ensure your measurements were accurate? _____

_____

How did you ensure your measurements were precise? _____

_____

What data did you collect? _____

_____

What conclusions can you draw from the data? _____

_____

Further extension - Pressure increases with depth.

Method

- Take an empty cool drink container and make three holes in a vertical line down its side.
- Fill a measuring jug or another empty bottle with water.
- Go outside onto a grassed or concrete area.
- With the holes on the side of the bottle pointing away from your body, rapidly fill the bottle with water.
- Observe the waterspouts and draw your observations on the bottle provided (right)

Create a Cavern – Student Activity

Discussion
How can you tell that pressure increases with depth in this experiment?

_____

Is there any other data you could collect that would support the hypothesis that the lowest spout was under greatest pressure?

_____

Interesting fact
The ***Pascal*** (Pa) is named after the French philosopher and scientist Blaise Pascal. It is a measurement of force per unit area. One Pa is the pressure one newton exerts on one square meter.
Standard atmospheric pressure at the surface of the earth is 101325 Pa.
A megapascal MPa is 1,000,000Pa.
Pressure at the foot of a 3km mine can be 80Mpa (9x greater than at surface)
Pressure at the foot of a 4km mine can be 110MPa (108.6x greater than at surface)