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Geoscience Education

Plate Tectonics

*Teacher Notes and
Student Activities*

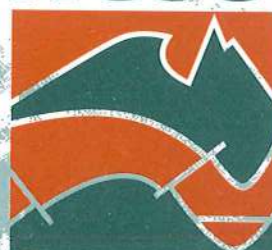
by Gary B. Lewis

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Gary B. Lewis
1994

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The Earth's Major Crustal Plates

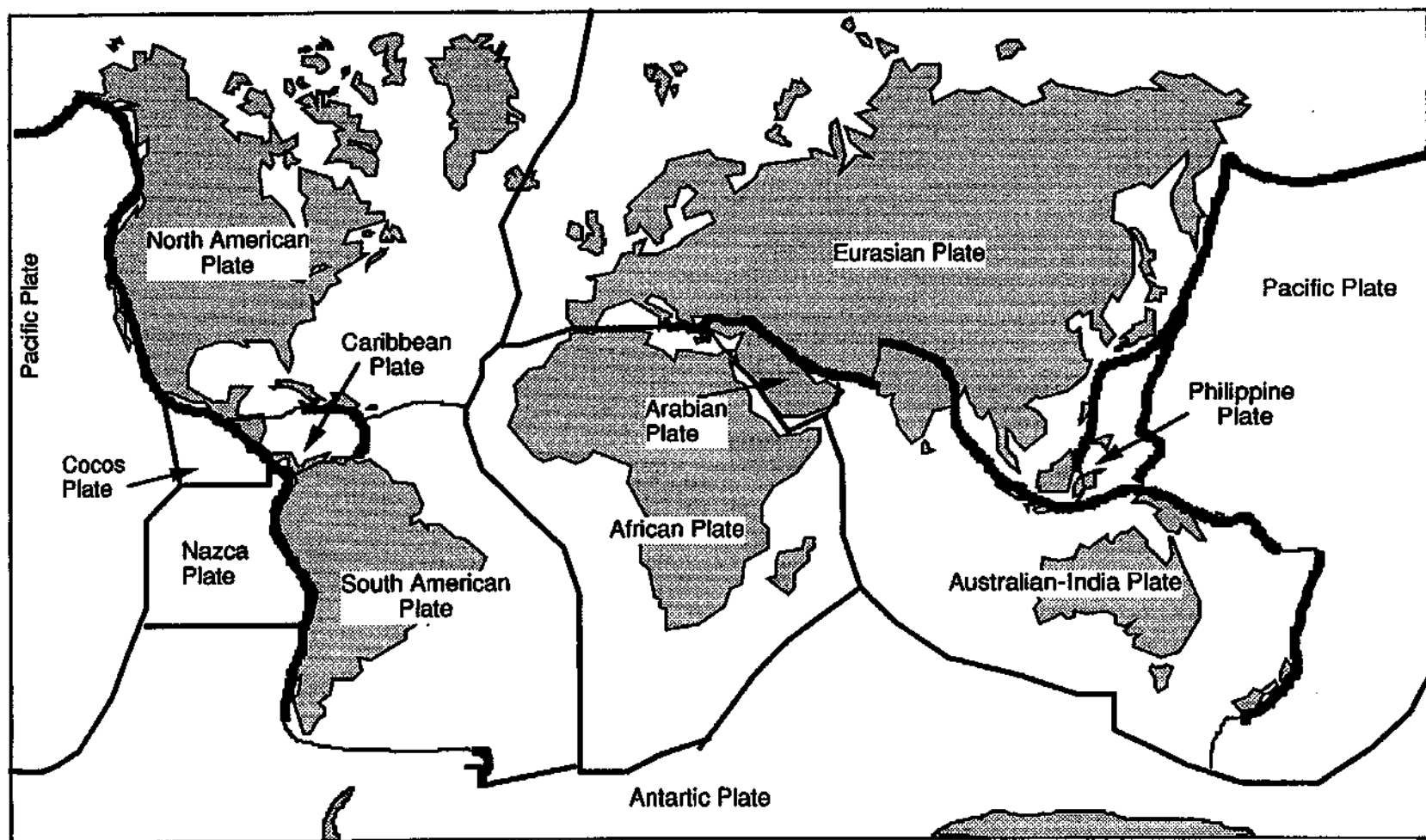


Plate Tectonics

1. The Theory

The Earth's crust is broken into about 12 rigid plates which slide over a semi-molten plastic layer of the mantle. There are three types of plate boundaries :

1. Spreading or divergent boundaries — where plates are moving apart.
2. Transform fault boundaries — where plates are moving past each other.
3. Subduction or convergent boundaries — where one plate overrides another plate.

Each plate is bounded by some combination of these three plate boundary types.

The material making up the plates can be divided into two types :

- i. Oceanic crust
- ii. Continental crust

The driving force for plate tectonics is slow moving convection currents in the underlying plastic mantle material.

Plate Tectonics Model

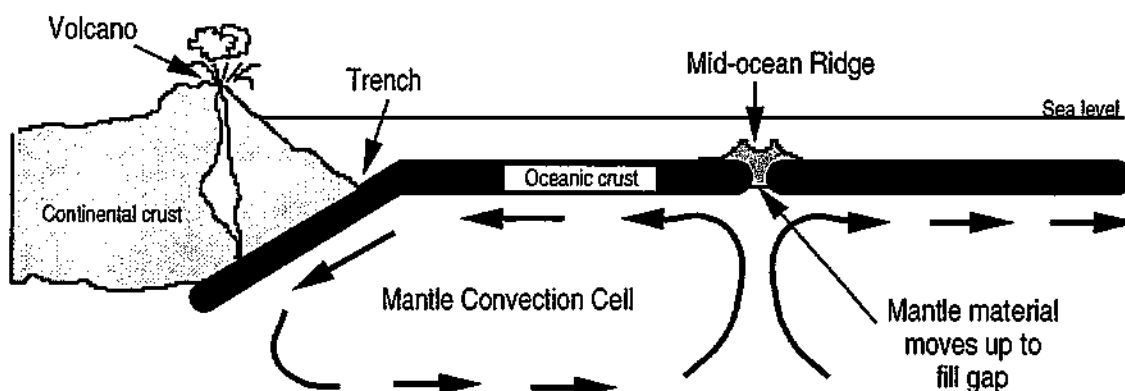


Figure 1. The Plate Tectonic Model.

2. History of the Theory

1600 —development of a comprehensive world map (missing details of some continents such as Australia and Antarctica).

1620 —*Francis Bacon* noted the similarity of the shape of the continents on either side of the Southern Atlantic — Africa and South America.

1666 —*François Placet* suggested that prior to the Great Flood the land was undivided by oceans and that the Atlantic formed when Atlantis sank.

- 1858 — *Antonio Snider* developed a theory that when the Earth cooled from a molten mass continents formed only on one side. This created instability causing the Americas to be pulled away from the rest of the continents.
- 1879 — *Sir George Darwin* said that the Pacific Ocean was the scar left behind when the Moon pulled away from the Earth. After this happened, the continents moved to create a balanced planet.
- 1890s — *Edward Suess* suggested that at one stage all the continents were joined as one massive continent which he called Gondwanaland. His evidence for this was the location of mountain ranges and common fossils.
- 1924 — *Alfred Wegener* developed the theory of Continental Drift to explain the similarities of rocks, fossils and other geological structures on either side of the Atlantic. At this time it was accepted that the continents sat like icebergs on the mantle and as the continents eroded they rose out of the mantle. Wegener suggested as well as moving up and down in the mantle, continents could move sideways in the mantle.
- *Wegener* was a meteorologist and his theory was not well accepted. (He died on an expedition in Greenland collecting ice samples).
- 1928 — *Arthur Holmes* suggested that convection currents in the mantle as the driving force of continental drift. He had no evidence to support his theory.
- 1950s — Extensive mapping of the ocean floor, especially the Mid-Atlantic Ridge.
- 1960s — *Harry Hess* suggested that sea floor separates at the mid-oceans ridges and new sea floor is created by up-welling of the mantle.
- 1970s — Theory of plate tectonics well accepted.

3. The Earth's layers

The Earth consists of a number of layers, each with different properties. Our knowledge of these layers has largely come from the study of earthquake waves.

The Core

The Core, consisting of the solid Inner Core and liquid Outer Core, is about 6940km in diameter. It is made up of very dense iron-nickel rich mixture. The temperature at the centre of the core is thought to be around 4000°C. The movement of the Core layers, either the Inner Core rotating in the Outer Core or the Outer Core moving around the Inner Core, causes the Earth's magnetic field.

The Mantle

The Mantle consists of a number of zones. It is made up of rock materials which is ultra-mafic in composition — i.e. rocks which contain iron, magnesium and low in silicon. A zone in the uppermost Mantle, the Asthenosphere, is very plastic (semi molten) in nature. Below the Asthenosphere the Mantle becomes more rigid. The boundary between the Crust and the Mantle is called the *Mohorovicic Discontinuity* (Moho for short).

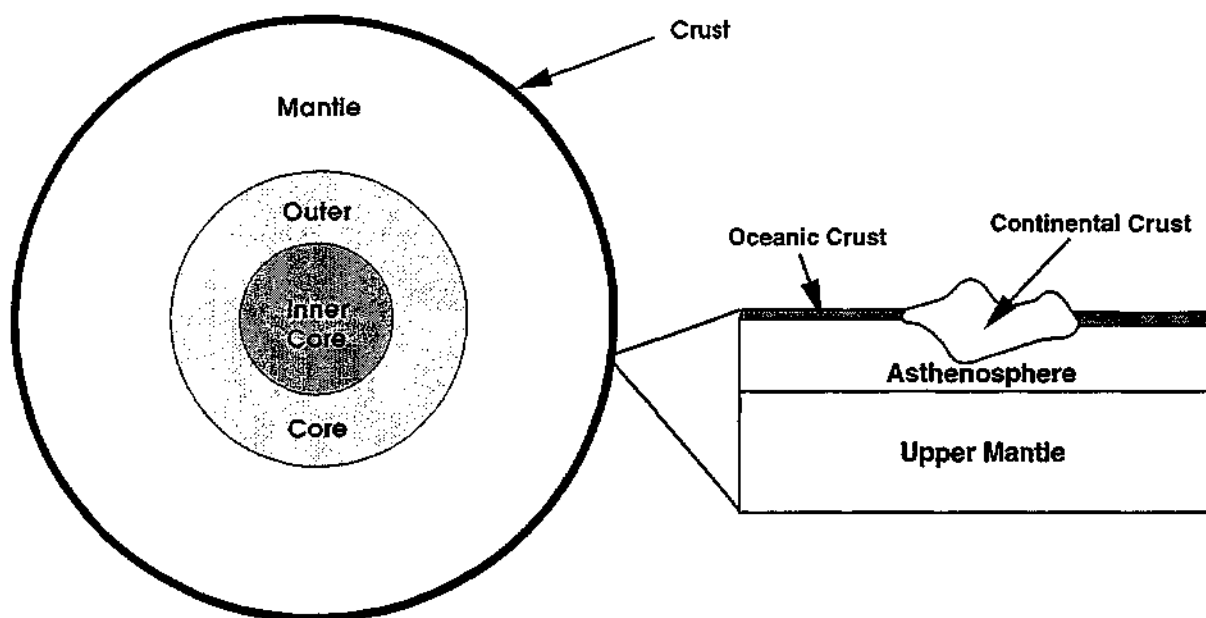


Figure 2. Structure of the Earth.

The Crust

The Crust is the thinnest layer of the Earth. At its thickest point, at mountain ranges, it is around 35–50km thick and in the ocean basins it is around 5–10km thick.

The crust can be divided into two types, Continental Crust and Oceanic Crust.

Continental Crust

Continental Crust is made up of rocks that are either igneous, sedimentary and metamorphic in origin. Almost all the of these rocks are rich in silicon and aluminium. The average density of the Continental Crust is 2.7g/cm^3 . The Continental Crust does not end at the shoreline but extends off-shore as the Continental Shelf. At the edge of the Continental Shelf is the Continental Slope which marks the boundary between Continental Crust and the Oceanic Crust.

Oceanic Crust

Oceanic Crust is made up of a layer of basalt lying on a band of gabbro. A thin layer of oceanic sediments accumulate on top of the basalt layer. The average density of Oceanic Crust is 3.0g/cm^3 . A feature of Oceanic Crust are long volcanic ridges which display a distinctive rift valley at their crests. These areas are volcanically highly active.

4. The three types of Plate Boundaries

Every plate interacts with a number of other plates at its edges. These boundaries fall into three main types, each having distinctive features which can be seen, or felt, at the Earth's surface.

Each type of boundary experiences earthquakes as the plates move past, over or under each other. There is a range of depths of earthquakes at the different types of plate boundaries.

Divergent Boundaries — zones of spreading

At these zones, two plates are moving away from each other. In the gap formed between the two plates, molten material from the upper mantle wells up to form a chain of volcanoes creating long ridges. All of these zones are found under the ocean and the ridges are called mid-ocean ridges. An exception to this is Iceland, where the mid-Atlantic ridge volcanoes have become so large that they have emerged from the ocean. At these ridges new oceanic crust is produced as the plates move apart. This new crust is added to both plates. The major rock type is basalt. (Figure 3a).

Along these zones the rate of spread can become uneven causing large transform faults to occur which displace the ridge crest. These faults remain active as the two plates continue to move (Figure 3b).

The earthquakes felt at divergent boundaries are shallow in depth (less than 30km). The crust is very thin at these locations and the majority of quakes are due to the movement of transform faults.

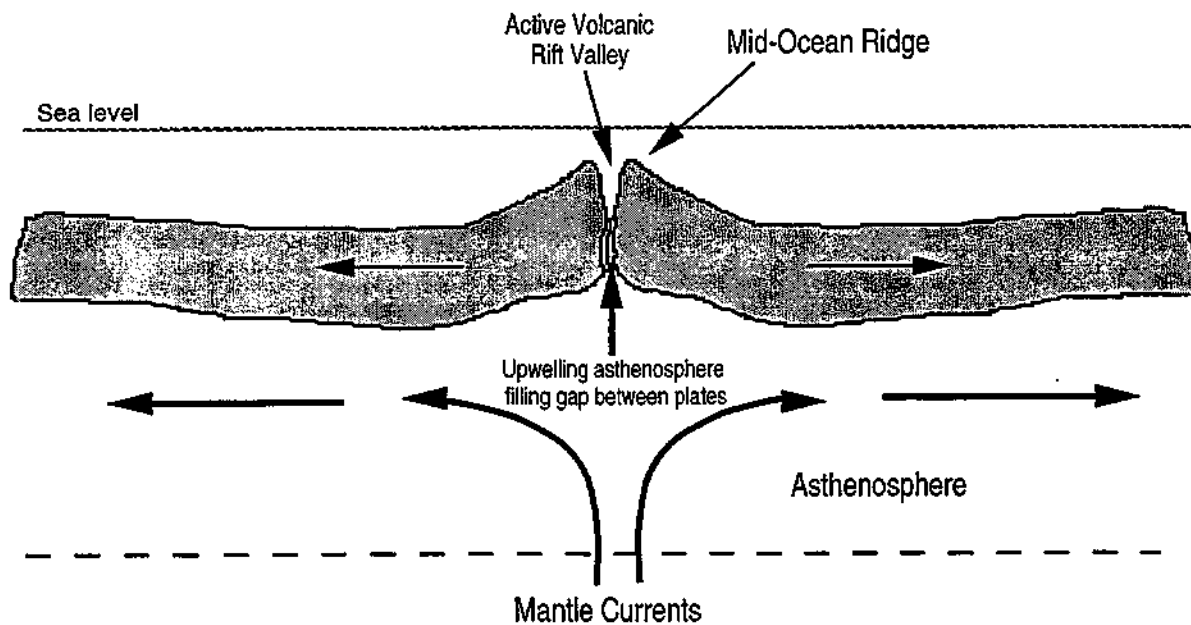


Figure 3a. Divergent Boundary.

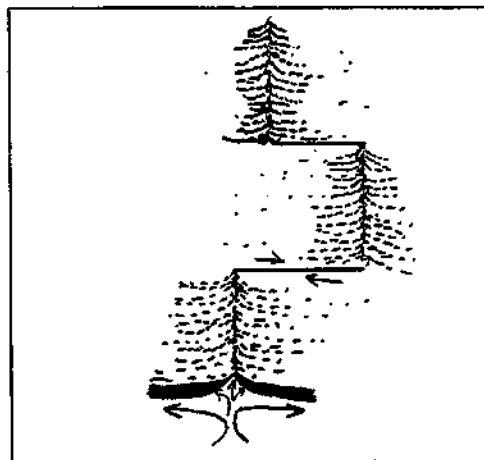


Figure 3b. A transform fault connecting segments of a mid-ocean ridge. (adapted from Marvin 73).

Convergent Boundaries — zones of collision

There are two types of convergent boundaries — each depending on the type of crust at the edge of the colliding plates.

Subduction Boundaries

These occur when a heavier oceanic plate collides with a lighter continental plate. The oceanic plate is forced under the continental plate with the oceanic plate being pushed down into the mantle (Figure 4). As the plates move a zone of grinding, known as the Benioff Zone, occurs between them. At the Benioff Zone, many earthquakes occur and the heat generated causes the continental crust to melt and rise to feed volcanoes on the edge of the continent. Eventually the end of the subducted plate melts into the mantle.

The boundary of the two plates is marked at the surface by a deep trench. These trenches form the deepest parts of the oceans. Sediments are deposited in these trenches and as the plates move the sediment is scraped off and added to the continental plate. An example of this type of boundary occurs between the western side of the South American Plate and the Nazca Plate. The trench occurs close to the coast and is known as the Peru-Chile Trench. The volcanoes form part of the Andes mountain range.

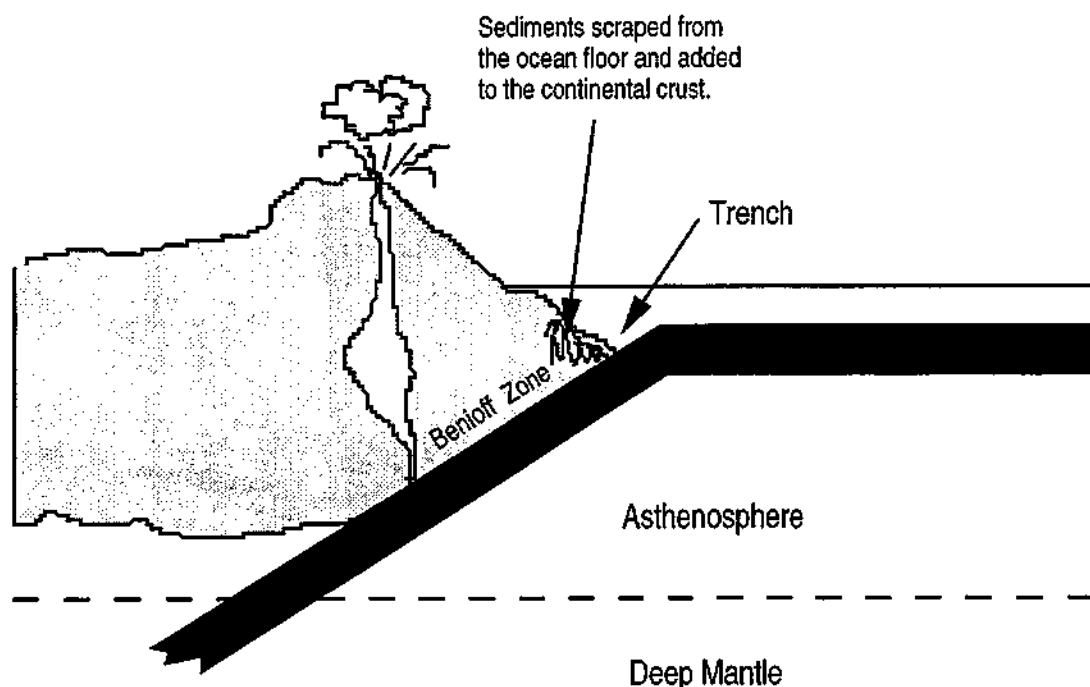


Figure 4. Subduction Plate Boundary.

In some locations the plate boundary occurs off-shore and the rising melted material from the Benioff Zone forms a chain of andesitic volcanic islands. These are known as island arcs. Japan is an example of an island arc structure. The trench occurs some 100km to the east of the islands. (Figure 5).

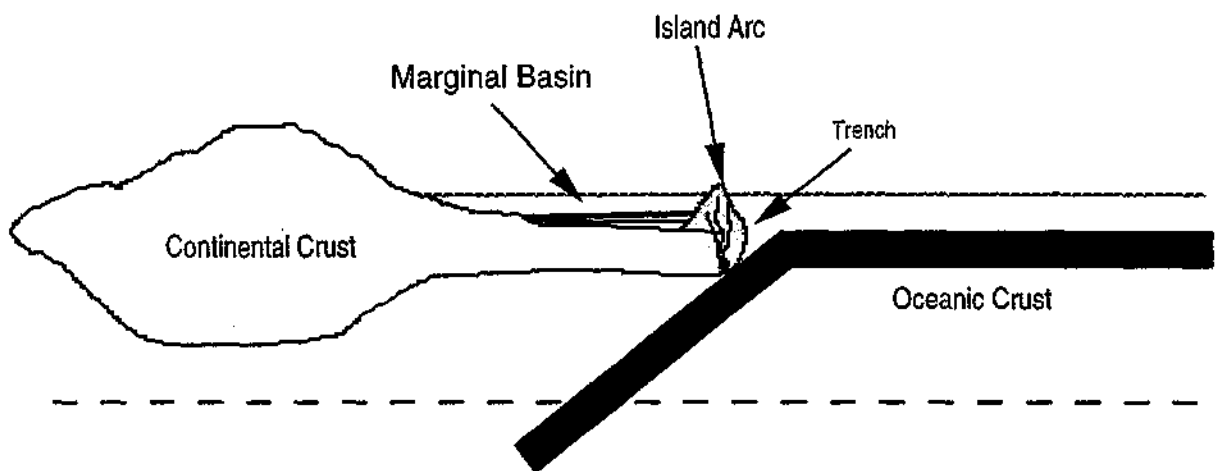


Figure 5. Island Arcs and Marginal Basins — Subduction zone features.

Continental Collision Boundaries

These occur when two continental plates collide. As both plates are of the same density, one is not forced under the other. Instead large mountain ranges of folded rocks are formed. An example of this type of plate boundary occur where the Australian Plate collides with the Eurasian Plate forming the Himalayan mountain range.

These plate boundaries are not common. After a period of time the plate boundary will shift to form a subduction zone boundary. (Figure 6).

The earthquakes felt at convergent boundaries range from shallow to very deep in depth (up to 700km). As you move across the continental crust of subduction zones, the earthquake depths get deeper as the Benioff Zone dips into the mantle.

Transform Fault Boundaries

These boundaries occur where two plates are sliding past each other. The boundary between the plates is a complex transform fault zone. An example of this is where the Pacific Plate is moving past the North American Plate. The boundary is the San Andreas fault complex. The earthquakes at this type of boundary can be from shallow to medium depths.

Summary Table

<i>Boundary Type</i>	<i>Surface Feature</i>	<i>Earthquakes</i>
Divergent	• mid-ocean ridges	• shallow depth only
Convergent <i>Subduction</i>	• deep ocean trenches • onshore volcanoes	• shallow to very deep moving from the trench
<i>Collision</i>	• high fold mountains	• all depths
Transform	• fault features — scarps, cut streams etc.	• shallow to medium depth

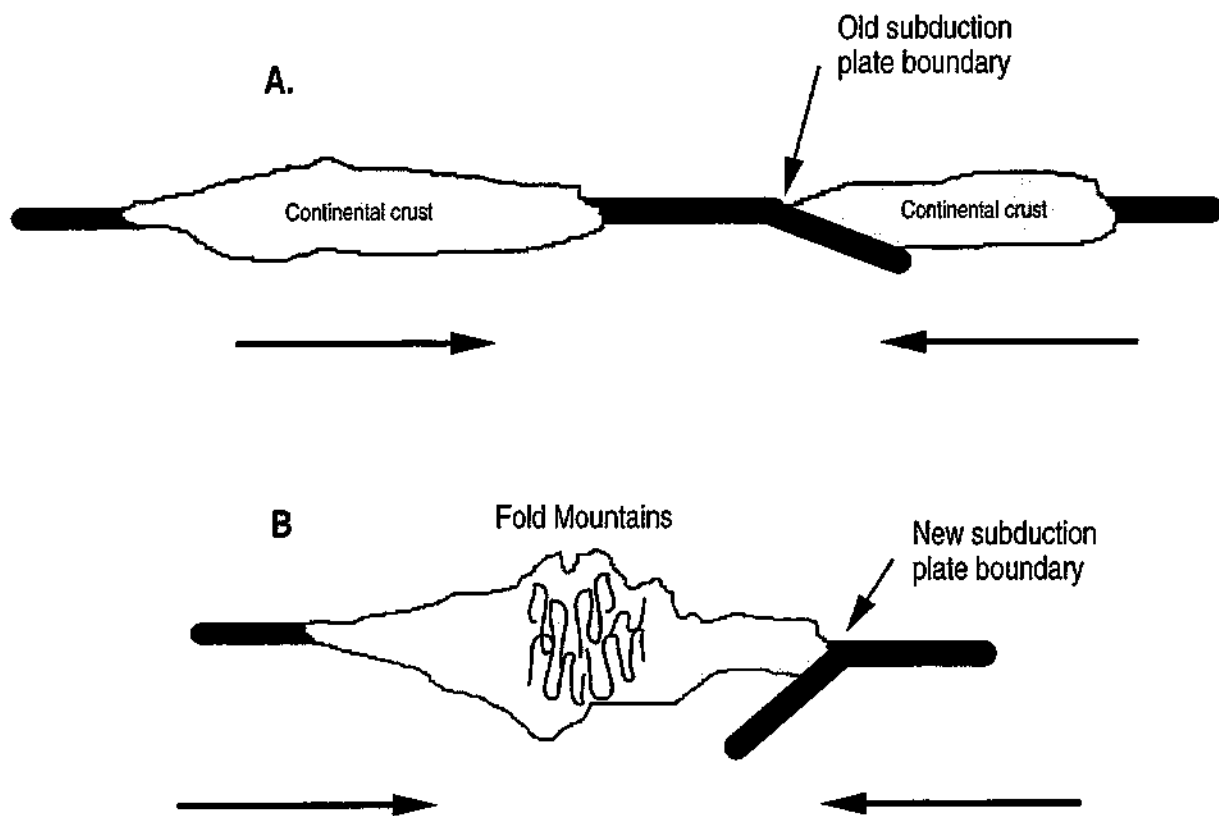


Figure 6. Collision Boundary. Two plates moving towards each other (A) with oceanic crust being subducted under continental crust. Eventually the two continental masses collide. As they are buoyant, they are not subducted and are forced up into a range of fold mountains. (B) The underlying mantle current continues to move forming a new subduction zone.

5. Evidence for Plate Tectonics

Shape of continents

The earliest evidence given for continental drift, the theory which developed into the theory of Plate Tectonics, was that the continental coast on the eastern side of the southern Atlantic Ocean was almost identical in shape to the continental coast of the western side of the southern Atlantic Ocean (Figure 7a). In fact the rock types, ages and fossil evidence on either side of the Atlantic matched when the two continents were put together. (Figure 7b).

Using the same type of information, all the continents of the Earth can be placed together like a jigsaw puzzle. Rather than using the coast lines, the edge of the continental crust (continental margin) is used. Around 400 million years ago, one super continent, "Pangaea" existed. Around 170 million years ago the now southern hemisphere continents formed one large landmass known as Gondwanaland. Around 100 million years ago Gondwanaland began to split up and the continents started to move in the directions in which they still move today. (Figure 8).

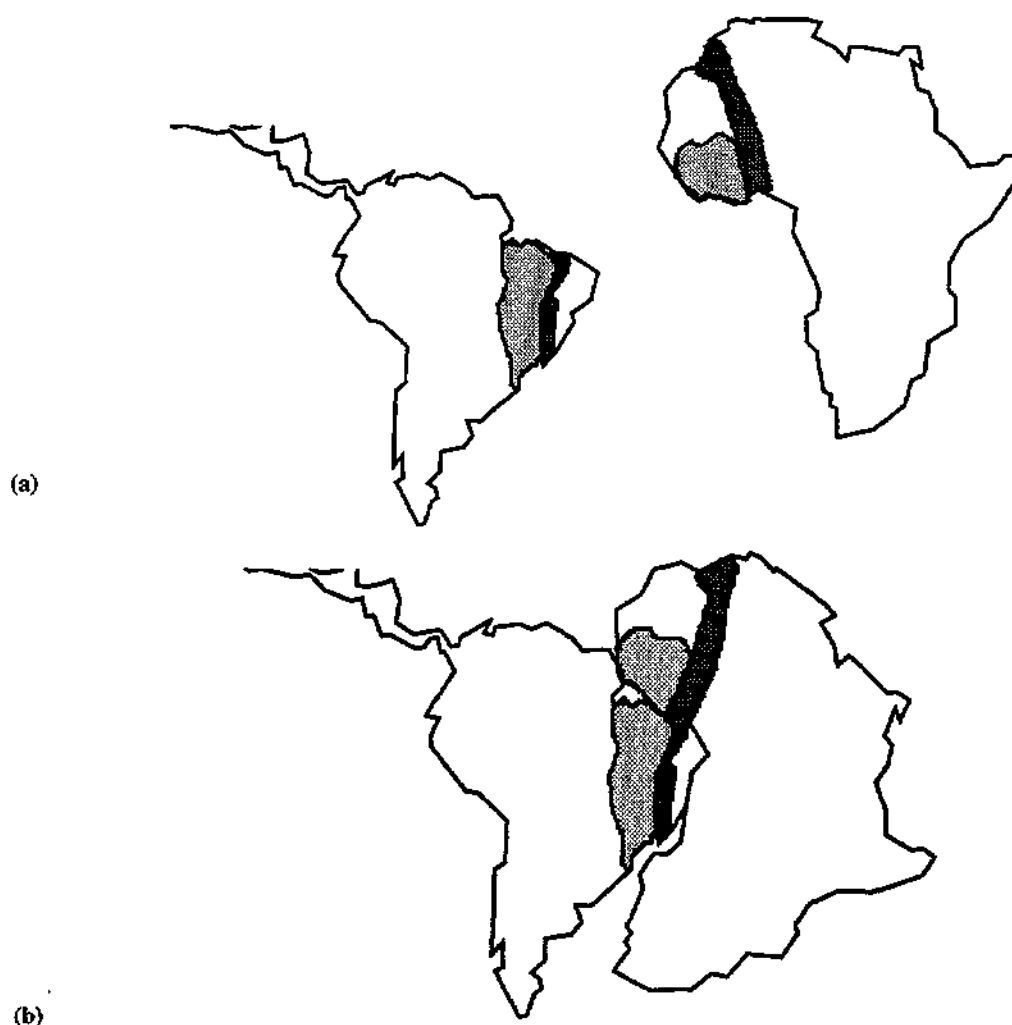


Figure 7. The Atlantic Ocean. As it is today (a) and a possible reconstruction before plate movement (b). (adapted from Marvin 1973).

Ages of rocks & Fossil Evidence

When the ages of rocks, found from radioactive decay dating, are compared across continents it is found that after the jigsaw puzzle is reassembled into Gondwanaland the ages on either side of the continental margins co-incide. Likewise the fossils contained in rocks also show similarities.

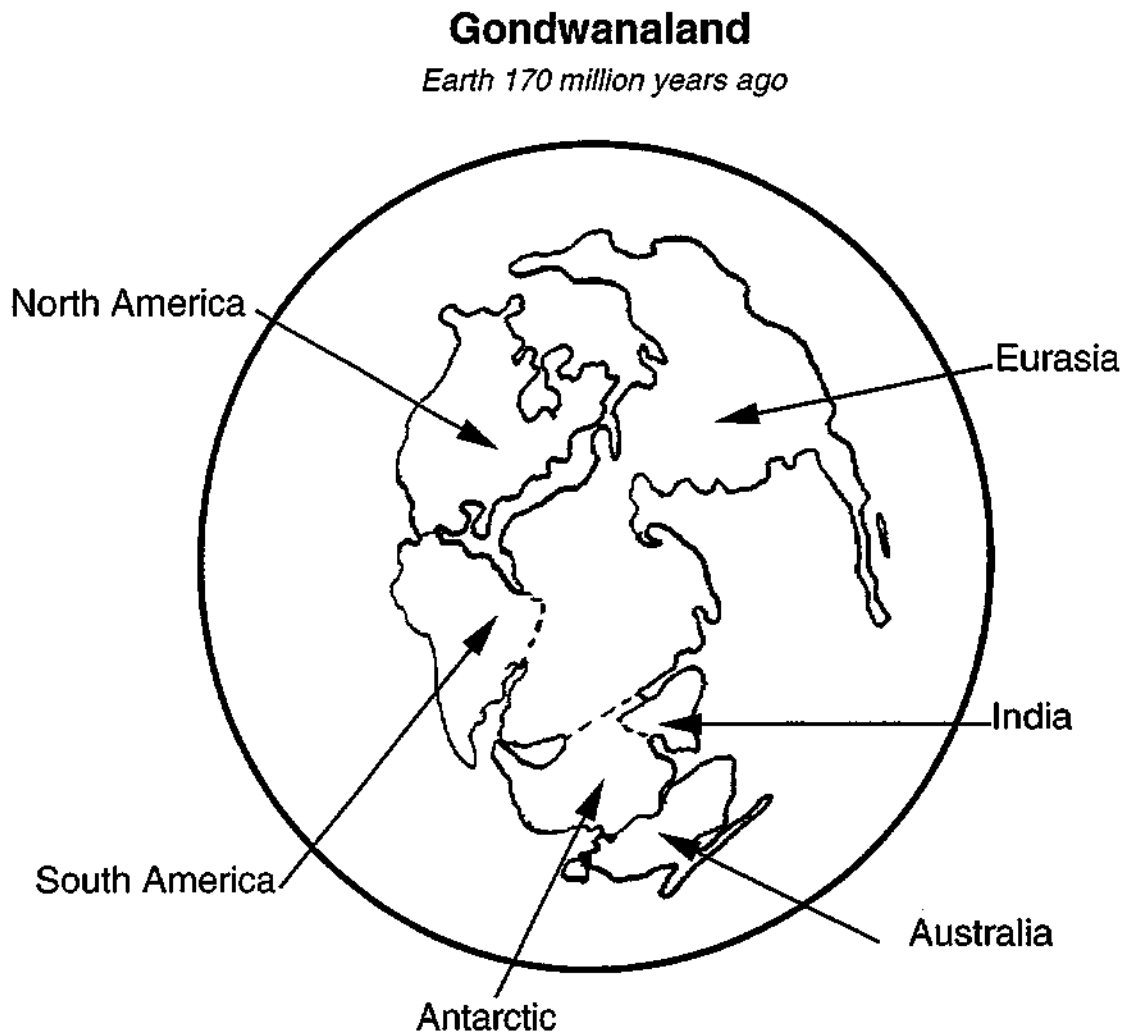


Figure 8. *Gondwanaland* (adapted from Clarke 1983).

Earthquake patterns

When the epicentres of earthquakes are plotted on the world map it is found that they form narrow zones. As earthquakes are produced by the grinding or snapping of one block of rock past another, these narrow zones represent the boundaries between crustal plates.

The earthquake zones can be divided into two types — shallow earthquake zones (<20km) and all-depth earthquake zones (0–700km). The shallow earthquake zones only occur along mid-ocean ridges where the crust is thin and movement is tensional (plates moving apart). The all-depth earthquake zones occur along trench and island-arc systems with the depth increasing away from the trench indicating the existence of the Benioff zone.

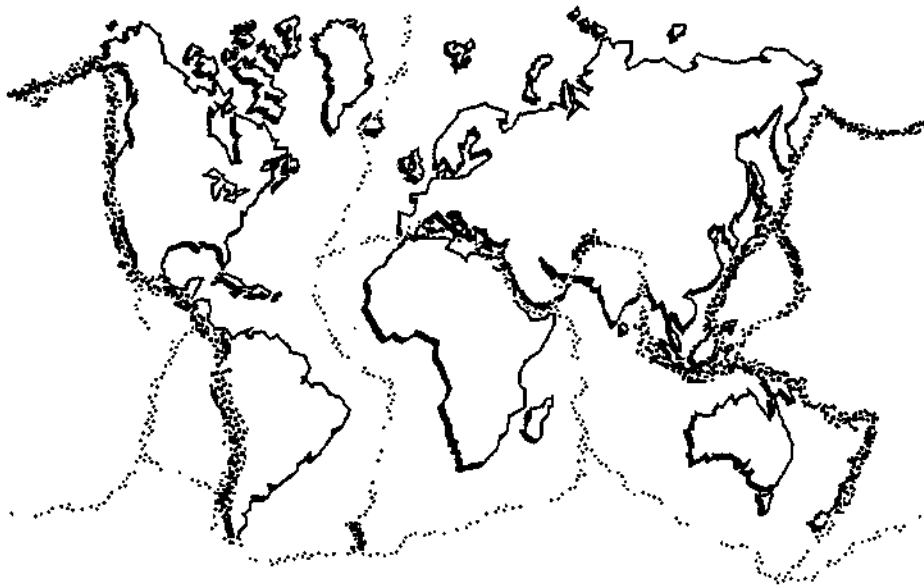


Figure 9. Epicentres of some 30 000 earthquakes recorded between 1961–1967. (adapted from Achache, (1987).

Volcano Patterns

Similar to earthquakes, the location of volcanoes closely reflects the boundaries of plates (Figure 10). This is especially evident around the coast lines of the Pacific ocean where an almost continuous line of volcanoes can be found and is referred to as the “Pacific Ring of Fire”. The type of lava extruded by the volcanoes gives geoscientists information about the type of crustal material being melted.

Mid-ocean ridges are chains of shield volcanoes extruding basaltic lavas. As these lavas are extruded under water, their outer crust cools quickly and solidifies. As the pressure of the still molten lava behinds builds up the crust breaks and a new blob of lava is exposed to the seawater. This action produces a unique lava structure known as pillow lava. These pillow lavas can often be seen in rocks forming the continents indicating a past tectonic environment.

The volcanoes making up island-arcs are more acidic in composition, that is, they contain minerals which have formed from the melting of continental crust rather than oceanic crust. Often these volcanoes show a sequence of lavas which change over time to become more and more acidic. The typical lava from these volcanoes is andesite and the volcanoes are normally composite volcanoes made from layers of lava and ash. Mt. St Helens, Mt. Rainier and Mt. Hood in north-western USA and Mt. Fuji in Japan are typical volcanoes of this type.

Hot-spot Volcanoes

As well as the volcanoes which line the edge of plates, some volcanoes are found away from the plate boundaries. These volcanoes are thought to have formed from mantle hot spots which melt the plate above forming a volcano. The Hawaiian Islands are a chain of volcanoes forming where the Pacific Plate is moving across a hot spot. The movement of the plate can be seen as the volcanoes in the chain become older as you move northwards.

Likewise, the Australian Plate has moved over a hotspot with ancient volcanoes found down the east coast from the oldest in north Queensland to the youngest in Victoria (Figure 11). The hot spot is now thought to be between Victoria and the west coast of Tasmania.

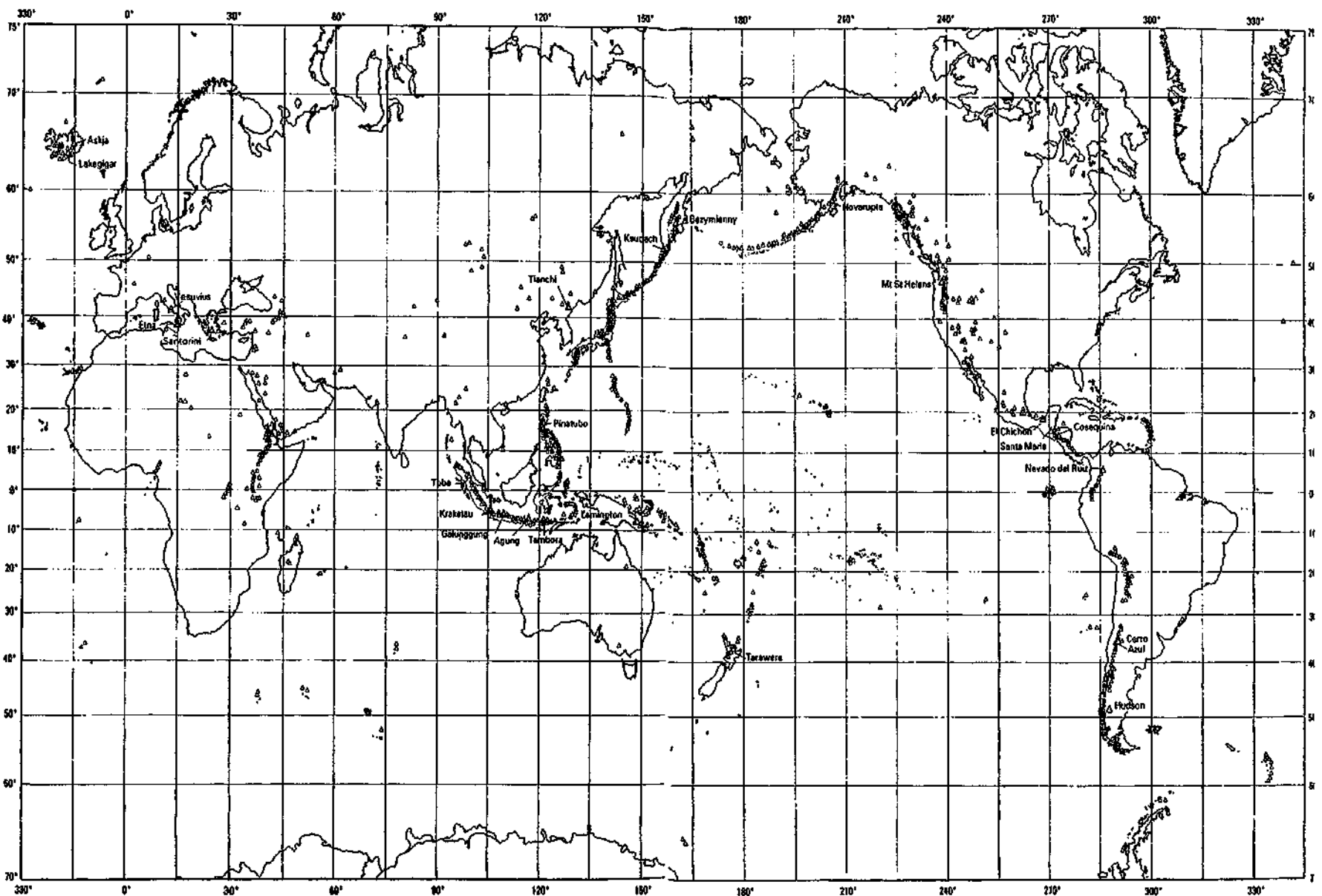


Figure 10. Locations of Earth's active volcanoes.

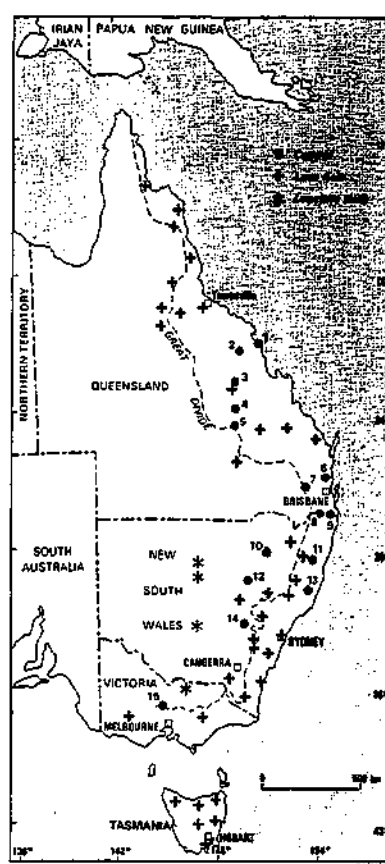


Figure 11. Hot Spot volcanoes in Australia. (1) Hillsborough, (2) Nebo, (3) Peak Range, (4) Springsure, (5) Buckland, (6) Glass House, (7) Main Range, (8) Focal Peak, (9) Tweed-Mt. Warning, (10) Nandwar, (11) Ebor, (12) Warrumbungles, (13) Comboyne, (14) Canobolas, (15) Macedon. (from Johnson RW 1989).

Ocean floor magnetic anomalies

The Earth has a natural magnetic field with a north and south pole, like a magnet. It is this field to which a compass needle aligns to point northwards (or in the southern hemisphere — southwards).

When rock is molten (such as lava) any magnetic minerals also align to this natural magnetic field. When the rock cools, these miniature “compasses” are frozen in that direction. Geoscientists can measure the direction that these minerals point using a device called a magnetometer.

When geoscientists look at ancient igneous rocks, they find that some show that the Earth's magnetic field was opposite to what is found today. In these rocks the minerals show that the north magnetic pole was once at the south geographic pole, and the south magnetic pole at the north geographic pole. (Presently and north and south magnetic poles are located near the north and south geographic poles). This change in poles is known as Polar Reversal and has taken place many times over the age of the earth.

Where two oceanic plates are moving apart from each other, volcanoes along an underwater ridge create new ocean floor on both plates. When a Polar Reversal occurs, the volcanic rocks record the change in their minerals. As you move away from the ridge the rocks display these Polar reversals as a series of magnetic stripes or anomalies. The ages of the Polar Reversals are known by dating the rocks using radiometric dating, so the rate that the plates are moving can be calculated by the thickness of the stripes in the pattern.

6. Why is Plate Tectonics important??

Understanding the dynamic nature of the Earth has provided geoscientists with models for finding mineral and energy deposits as well as helping in the prediction of natural hazards associated with the moving crust (earthquakes, volcanoes, tsunamis, landslides etc.).

Plate Tectonics and Mineral Deposits

Humans have been extracting, processing and using metals for centuries. Over this time, and especially in the last 100 years, the need for these metals has dramatically increased so that almost all deposits of metallic bearing minerals outcropping at the Earth's continental surfaces have now been discovered and, if possible, utilised.

By studying these deposits, geoscientists have developed models for the formation of these deposits based on the tectonic environment of the time. For example, many copper-lead-zinc deposits are found in rocks formed in ancient convergent plate boundaries. By searching in areas containing rocks formed in the same tectonic environment, geoscientists hope to find further deposits.

In a similar way, geoscientists recognised that some of these ancient deposits formed from the precipitation of dissolved metal salts in seawater. Their model involved the release of deep-crust super-hot water containing the dissolved minerals on to the sea floor where, on meeting the cold sea water, the minerals precipitated to form a layer on minerals. They then studied possible tectonic environments where this type of action may happen and discovered on the sea floor in the eastern Pacific a field of active "black smokers" — small chimneys releasing hot-mineralised water in the ocean, precipitating metal salts on to the sea floor.

Plate Tectonics and Oil

The formation of accumulations of oil depends on a special sequence of events and a particular tectonic setting. The sequence of events, namely the accumulation of organic matter in large amounts in an oxygen free environment, will not form a pool of oil which can be tapped unless the tectonic setting is such so the oil is trapped by the overlying geological structure.

The most favourable tectonic settings for the accumulation and trapping of oil is in marginal ocean basins. Margin ocean basins occur between subduction zone trenches/island-arcs and the edge of the continental coast. These basins provide stable environments for the accumulation of organic rich sediments and isolation from circulation major ocean currents (which are normally oxygen rich). The basins normally undergo slight folding providing geological traps for the accumulating oil (see Figure 5).

Geoscientists now search for oil traps in areas which have been (or are) margin basins.

Natural Hazards

By understanding the mechanisms which cause volcanoes, earthquakes and their associated hazards, geoscientists hope to provide better risk assessment information. This information may save lives by providing town planning authorities and building agencies with details of the possible earth and sea disturbances which may take place in a region.

Australian Geological Survey Organisation

AGSO's role is to provide exploration companies with large scale survey information which will aid these companies in targeting favourable tectonic settings for the accumulation of minerals and oil. This involves ground geological surveys, airborne and ground geophysical surveys and seismic surveys of ocean basins using a seismic ship.

AGSO is also involved in the scientific study of geohazards such as earthquakes, volcanoes and changes to the Earth's magnetic field.

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Earthquake Boundaries!

10 000 earthquake epicentres have been recorded on a map of the world. Can you use this data to locate the Earth's crustal plates?

Earthquakes occur where slabs of rock grind past each other. This occurs at the boundaries of the Earth's crustal plates as the plates move past each other, move apart from each other or one plate slides over the top of another plate.

While some earthquakes occur away from plate boundaries, the majority occur in zones along the boundaries.



Like a huge "Join-the-dots" puzzle, trace around the locations of the earthquakes to mark out the plates. In some places this will be easy — in some places it will be difficult.



Compare your plates with those of a friend. Do you agree on the location of the plates? Do you have some plate boundaries in different locations?

Geologists have identified the following major plates :

Australian plate

South American Plate

Antarctic Plate

African Plate

Pacific Plate

Eurasian Plate

North American Plate

Philippine Plate

Cocos Plate

Caribbean Plate

Nazca Plate

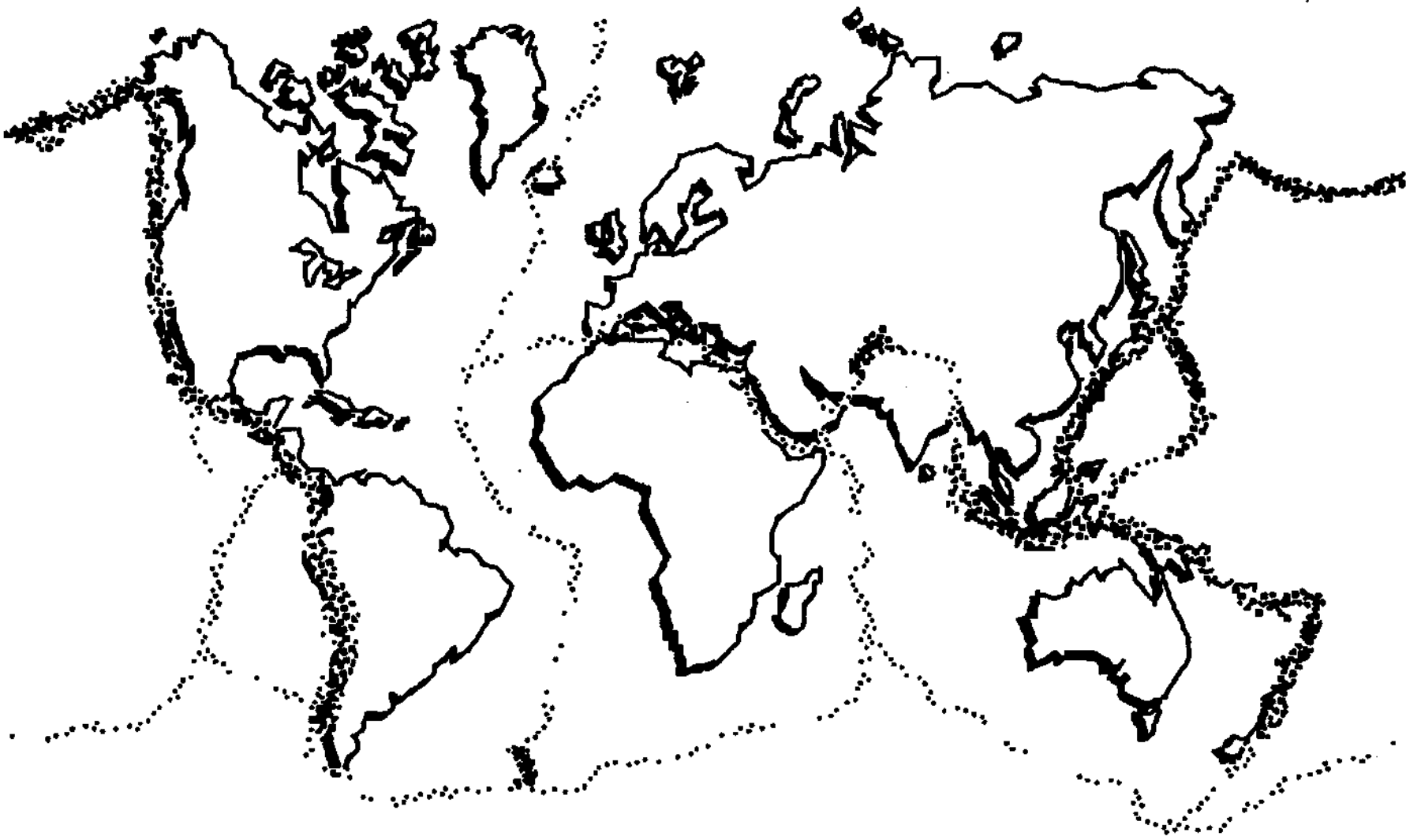
Arabian Plate



Try to identify these plates on your map. Use an atlas if you do not know where these places are located.

Some plate boundaries appear to be more active than others. Boundaries where one plate is being forced under another plate have a greater number of recorded earthquakes than the other types of boundaries.

Can you identify these plate boundaries. Mark them on your map with a different colour pencil.



Ocean Ridge Model

Oceanic crust makes up about 70% of the earth's surface. A feature of the ocean crust is the occurrence of long volcanic chains which make up a continuous ridges. These volcanic ridges mark the place where two plates are moving apart and new molten material wells up in the space between the two plates.

The spreading apart of the plates often is not uniform and large transform faults occur across the ridge. As the plates move, the plates grind past each other at these faults causing earthquakes.

This model shows how these faults are active. To make the model you will need :

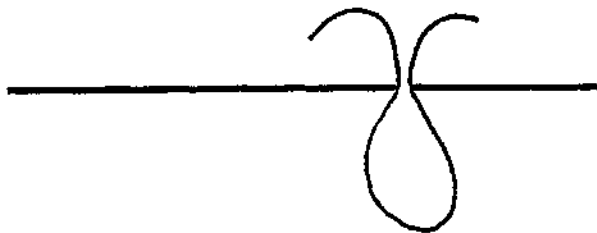
- Ocean Ridge Model templates (two sheets)
- cardboard piece the size of a piece of A4 paper
- scissors/sharp knife
- sticky tape
- glue

Step 1 | Glue the "Ocean Ridge Model" sheet onto the cardboard and allow the glue to dry. This will be the baseplate for the model.

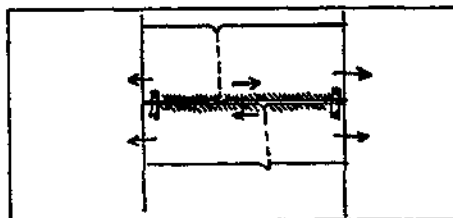
Step 2 | Cut the rectangles from the other sheet of paper.

Step 3 | Cut out the two slits where marked on the baseplate.

Step 4 | Feed the rectangles through the slits so they form a loop of paper at the back of the baseplate.



Step 5 | Pull both rectangle through the slits so that the "Australian Plate" ends touch the line at the top and the "Antarctic Plate" ends touch the line at the bottom. Tape the two rectangles together (but not to the baseplate) where marked.



To operate the model, hold the "Australian Plate" end with one hand and the "Antarctic Plate" end with the other hand and slowly pull apart. Look at the place where the two plates move past each other. This is the transform fault zone.

Ocean Ridge Model

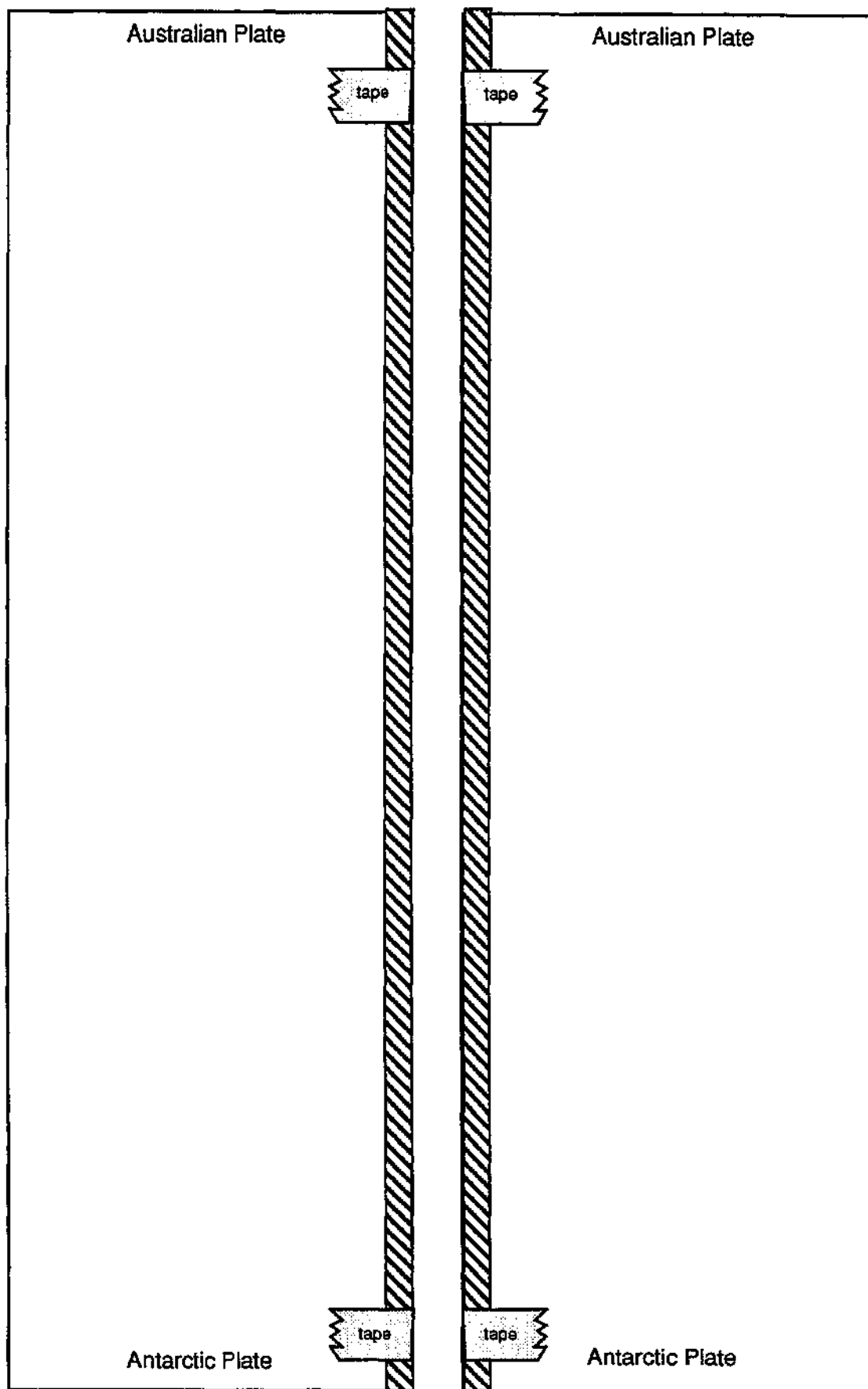
Glue this template to stiff cardboard
and cut out the slits marked

Cut out this slit



Cut out this slit

Cut out both rectangles



Continent Movement

Tectonicland

It is the year 2153 and you are a geologist on a space mission to Tectonicland. Your main role is to study the continents of the planet and how they have been affected by plate tectonics. You will use the age of rocks to find if the continents have ever been joined together in the history of the planet.

On a previous mission your assistant collected 16 rock samples and had them analysed for radioactive elements. The location of each of the 16 samples is marked on the map.

Sample	Radioactive Element	% of original mass remaining	Age of rock
1	U ²³⁸	67.5	_____ billion years
2	Th ²³²	90	_____ billion years
3	Th ²³²	95	_____ billion years
4	U ²³⁵	26	_____ billion years
5	U ²³⁵	95	_____ billion years
6	U ²³⁵	7.5	_____ billion years
7	U ²³⁸	66	_____ billion years
8	Rb ⁸⁷	96	_____ billion years
9	U ²³⁵	94	_____ billion years
10	U ²³⁵	10	_____ billion years
11	U ²³⁸	57.5	_____ billion years
12	U ²³⁵	40	_____ billion years
13	U ²³⁵	40.5	_____ billion years
14	U ²³⁸	85	_____ billion years
15	Th ²³²	90	_____ billion years
16	U ²³⁸	99	_____ billion years



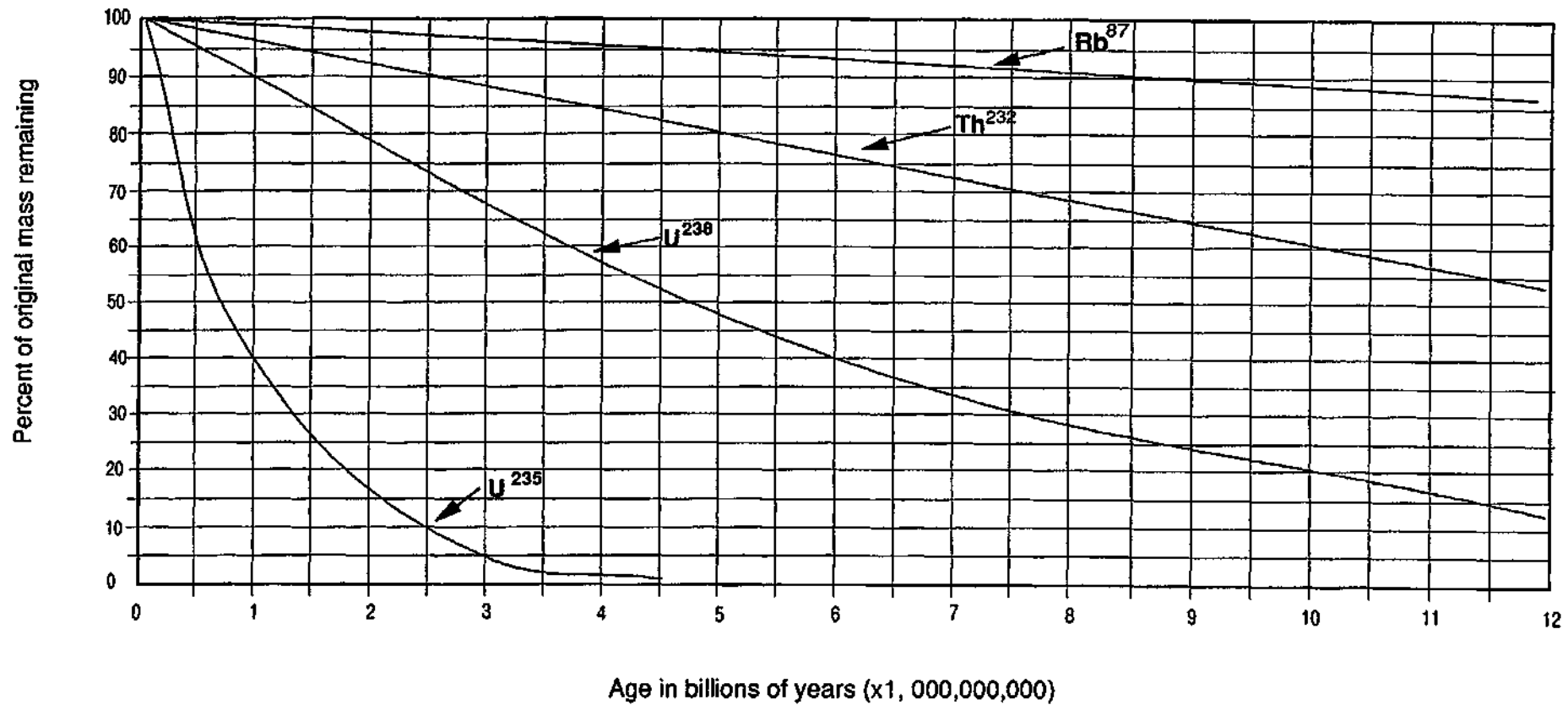
Using the radioactive decay curves, find the approximate age for each sample and complete the table. Also write the ages against the location numbers on the map.

Cut out both continents from the map and see if you can fit them together so that rocks of the same age match up between the two continents.



HINT : Locations 9 and 5 have rocks of the same age — try bending the continent to fit these together first.

Radioactive decay curves



Map of
Tectoniland

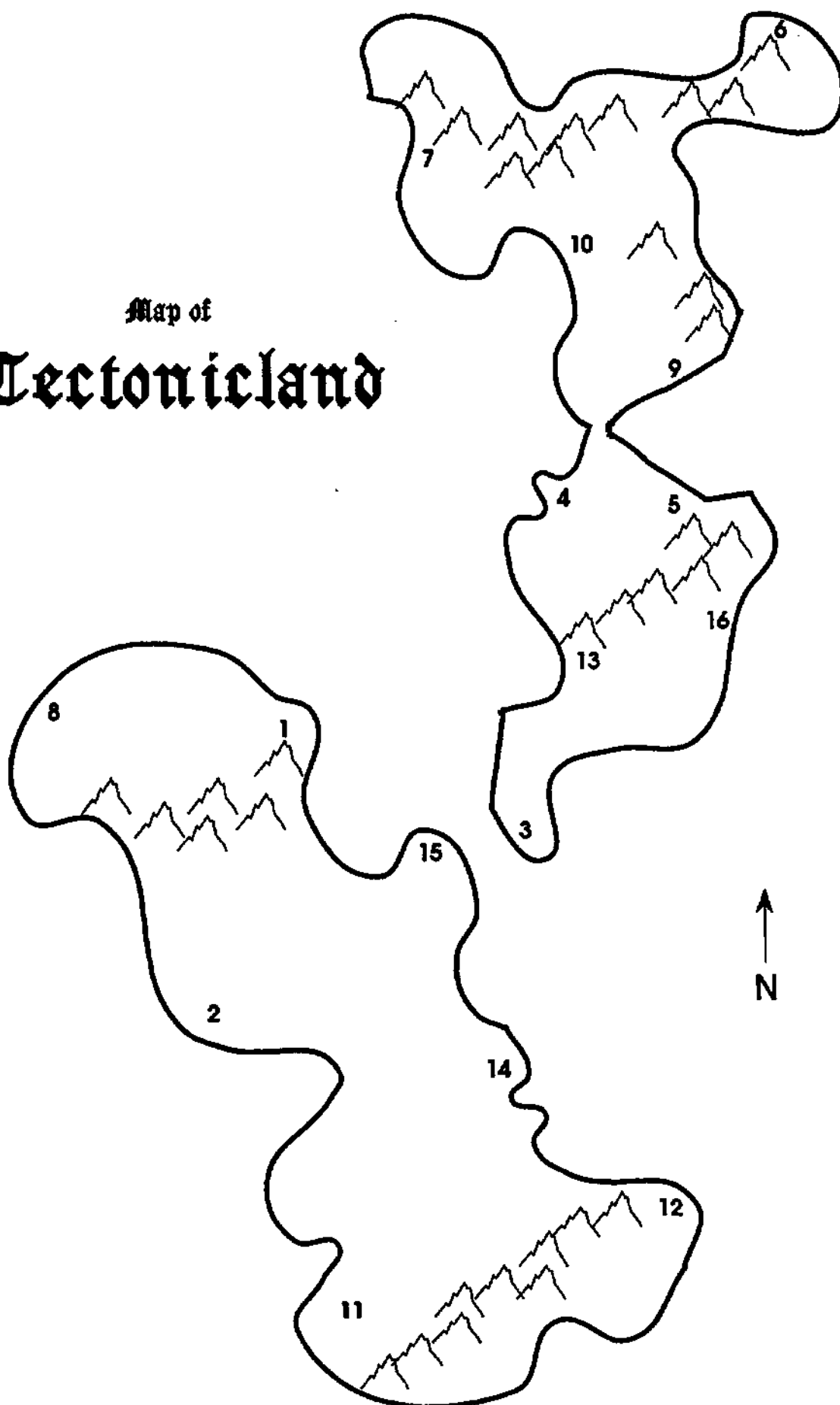


Plate Movement

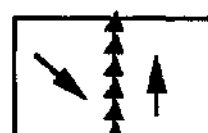
Using these simple diagrams, mark on the three diagrams below the type of boundaries which occur between the plates. You can use the same symbols, or use a different colour for each type of boundary.



Subduction



Subduction



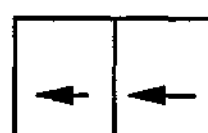
Subduction



Divergent

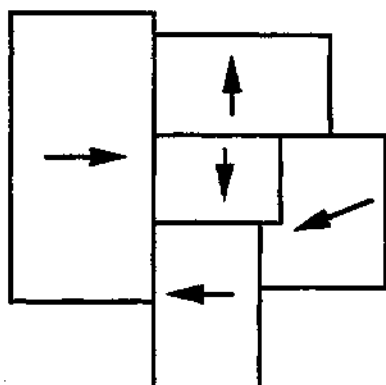


Transform
fault

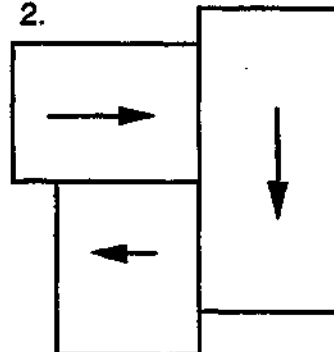


Dormant

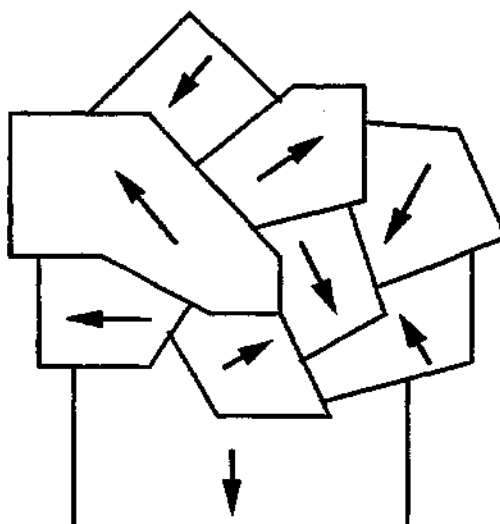
1.



2.



3.



Voyage of the "Tectonica"

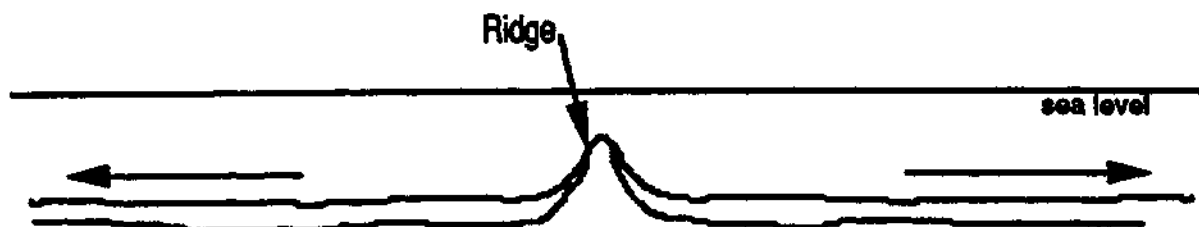
Background Information

The Earth has a natural magnetic field with a north and south pole, like a magnet. It is this field to which a compass needle aligns to point northwards (or in the southern hemisphere — southwards).

When rock is molten (such as lava) any magnetic minerals also align to this natural magnetic field. When the rock cools, these miniature "compasses" are frozen in that direction. Geoscientists can measure the direction that these minerals point using a device called a magnetometer.

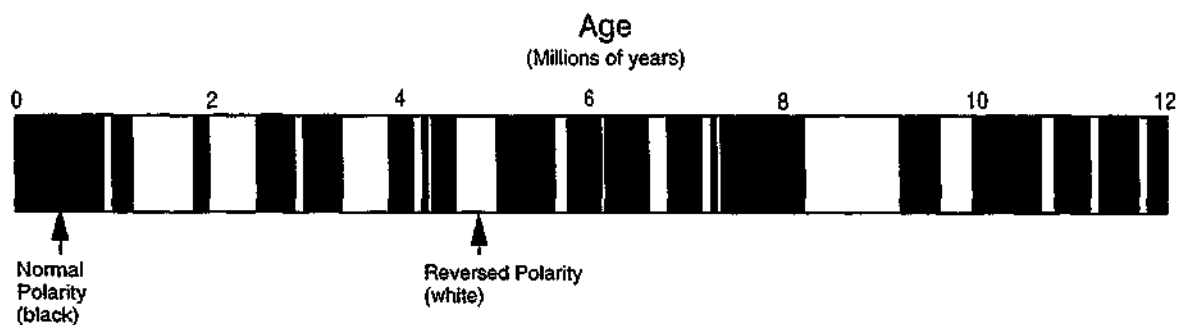
When geoscientists look at ancient igneous rocks, they find that some show that the Earth's magnetic field is opposite to what is found today. In these rocks the minerals show that the north magnetic pole was once at the south geographic pole, and the south magnetic pole at the north geographic pole. (Presently and north and south magnetic poles are located near the north and south geographic poles). This change in poles is known as Polar Reversal and has taken place many times over the age of the earth.

Where two oceanic plates are moving apart from each other, volcanoes along an underwater ridge create new ocean floor on both plates.



When a Polar Reversal occurs, the volcanic rocks record the change in their minerals. As you move away from the ridge the rocks display these Polar reversals as a series of magnetic stripes or anomalies.

Ocean Floor Magnetic Anomalies



The ages of the Polar Reversals are roughly known, so the rate that the plates are moving can be calculated by the thickness of the stripes in the pattern. Recognising the pattern of stripes is the first step in calculating the rate of spread.

Activity

The "Tectonica" is a survey ship which has instruments which can measure the change in polarity of volcanic rocks which make up the ocean floor. During a cruise in January 1994, four survey lines were taken across the plate boundary between the Australian Plate and the Antarctic Plate. It is your task to convert the raw data and calculate the rate of spread of these two plates.

As the ship moves along a survey line it records the distance at which any change in polarity is found.

The information you have been given :

- i. "Survey Line Data" for the four survey lines (A,B,C and D).
- ii. "Survey Lines of Southern Ocean" a map of the locations of the four lines.



Step 1. Convert to scale

The distances for each recording need to be converted into millimetres (mm) so you can plot them on the map. The conversion factor is 1/20. Divide each distance (km) by 20 and write the answer in the "Map mm" column. Note that survey lines B,C and D do not start at 0 km. You will need to adjust these by first subtracting the first recording.

Example — Survey Line B

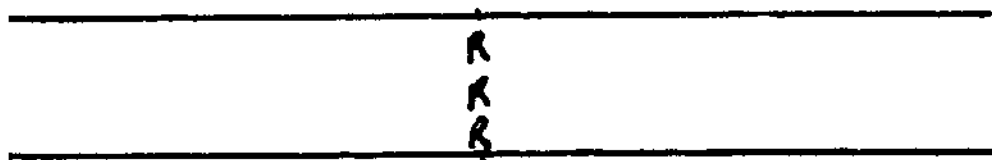
	Map
km	mm
800	0
920	$(920-800)/20 = 6$
1000	$(1000-800)/20 = 10$

Do the conversions for all four survey lines.



Step 2. Mark the ridges.

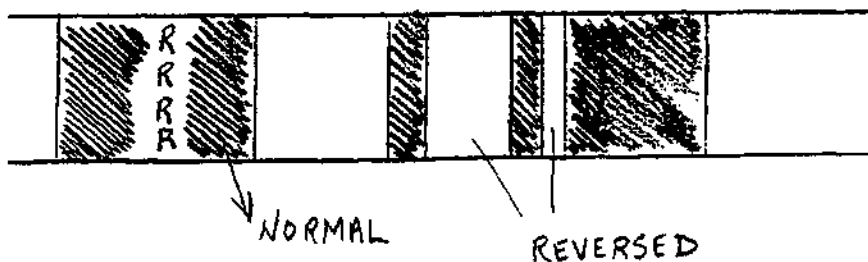
On the "Survey Lines for Southern Ocean map" measure the distance you calculated in mm from the left edge of the survey line A for the volcanic ridge and mark this location with a capital "R".





Step 3. Mark the reversal points.

Start on the left side of Survey line A and mark each polar reversal with a line. Note that the ridge lies in the middle of a stripe. Once you have marked each polar reversal, colour those areas which have normal polarity in black. Leave those zones of reverse polarity white.



Step 4. Age the stripes.

Using the "Ocean Floor Magnetic Anomalies" data given at the start of this exercise, find the pattern of polar reversals on each side of the ridge in Survey Line A. Remember that the volcanic ridge is creating new materials and represents 0 millions of years ago. (You may have to turn one upside-down and the pattern is not exact.)

?

Find the stripe that represents the polar reversal that occurred 2 million years ago. How far is this from the volcanic ridge in km? (Every mm=20km)

_____ km

?

How far does the ocean floor move from the ridge every year? (show your calculations).



Step 5. Complete the Survey Lines B,C and D as in Steps 2 and 3.

?

What observation can you make about the position of the Ridge in Survey Line B?

?

How far is the ridge in Survey Line B horizontally away from the Ridge in Survey Line A in km?

?

What geological structure might occur between Survey Line A and Survey Line B to offset the Ridge?

As Tectonic moves along a survey line it only measures the polarity of the rocks directly below the ship. On the map lines you have drawn you have made the lines bigger than the ship can actually see. If you draw a line down the middle of the survey line box you will mark the actual position of the survey ships path.



Mark this line on Survey Line C.

Can you suggest why Survey Line D crosses the Ridge twice?

Is this further evidence for the same geological structure which offsets the Ridge in Survey Line B ?

Survey Ship "Tectonica" Survey Line Data

km	Map mm	Survey Line A	km	Map mm	Survey Line B	km	Map mm	Survey Line C	km	Map mm	Survey Line D
0		Normal	800		Reversed	1600		Reversed	1200		Normal
60		Reversed	920		Normal	1640		Normal	1240		Reversed
80		Normal	1000		Reversed	1720		Reversed	1360		Normal
220		Reversed	1040		Normal	1760		Normal	1400		Reversed
300		Normal	1100		Reversed	1820		Reversed	1420		Normal
380		Reversed	1200		Normal	1920		Normal	1600		RIDGE
580		Normal	1240		Reversed	1960		Reversed	1780		Reversed
780		Reversed	1360		Normal	2080		Normal	1800		Normal
800		Normal	1420		Reversed	2140		Reversed	1840		Reversed
860		Reversed	1440		Normal	2160		Normal	2080		Normal
920		Normal	1600		RIDGE	2300		RIDGE	2120		Reversed
1080		Reversed	1780		Reversed	2480		Reversed	2140		Normal
1100		Normal	1800		Normal	2500		Normal	2320		RIDGE
1240		Reversed	1860		Reversed	2560		Reversed	2500		Reversed
1320		Normal	1960		Normal	2680		Normal	2520		Normal
1400		Reversed	2020		Reversed	2720		Reversed	2540		Reversed
1460		Normal	2120		Normal	2820		Normal	2680		Normal
1640		Reversed	2180		Reversed	2900		Reversed	2720		Reversed
1680		Normal	2220		Normal	2940		Normal	2820		Normal
1760		Reversed	2300		Reversed	3020		Reversed	2900		Reversed
1860		Normal	2380		Normal	3120		Normal	2920		Normal
1900		Reversed	2400		END OF LINE	3180		Reversed	3020		Reversed
2020		Normal				3200		Normal	3100		Normal
2060		Reversed				3280		Reversed	3140		Reversed
2100		Normal				3380		Normal	3160		Normal
2280		RIDGE				3460		END OF LINE	3240		END OF LINE
2460		Reversed									
2500		Normal									
2540		Reversed									
2660		Normal									
2700		Reversed									
2800		Normal									
2860		Reversed									
2900		Normal									
2980		Reversed									
3080		Normal									
3100		END OF LINE									

Survey Ship "Tectonica" - Survey Lines of Southern Ocean

46 lat. 120 long.

Distances in Kilometres

