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PhotoMaster Format

Plate Tectonics

Year 9 Earth & Space Sciences

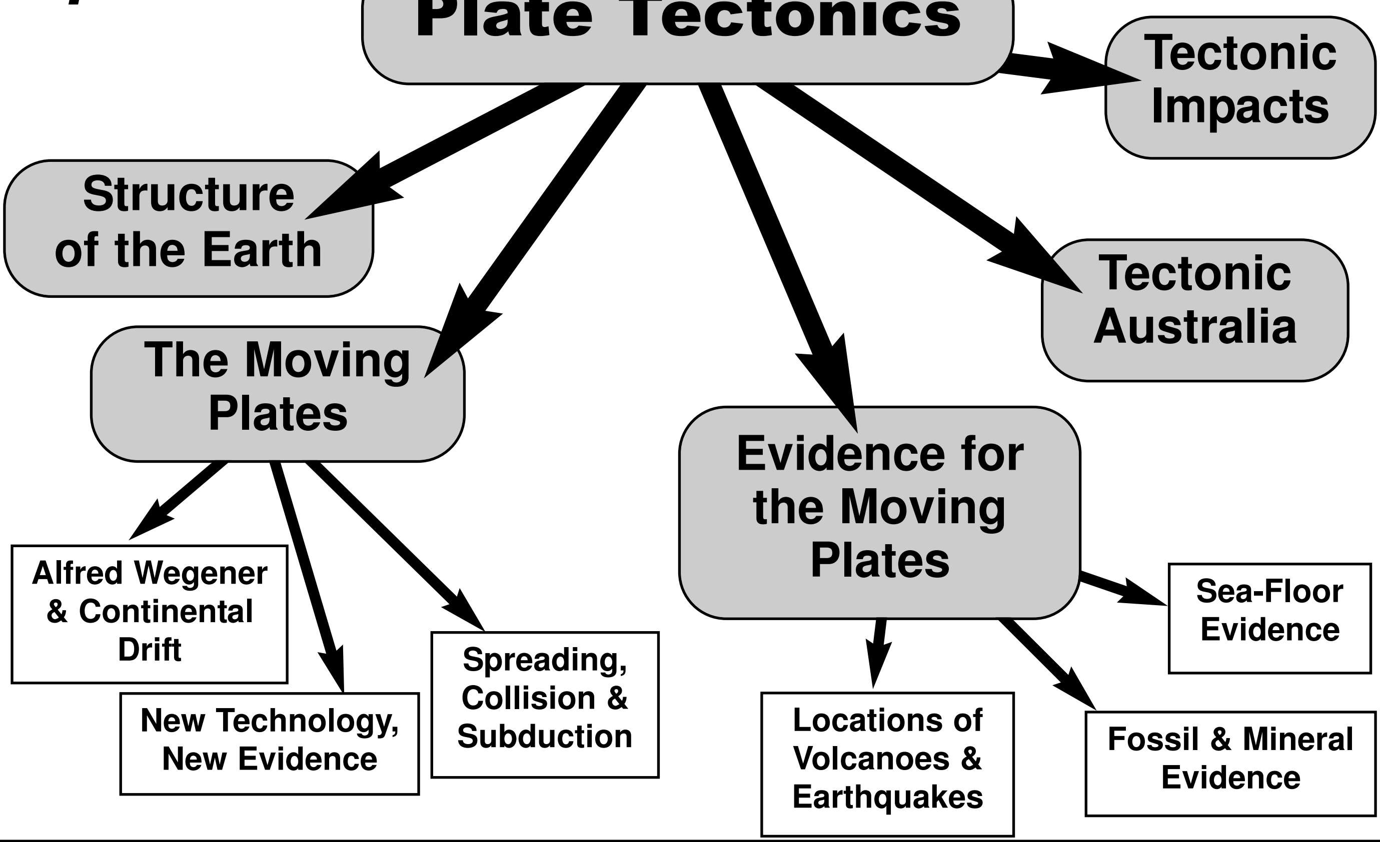
KISS topic number

Year level designation in Nat.Curriculum

Topic 17.9E

Science Understanding Strand
B = Biological Sciences
C = Chemical Sciences
E = Earth & Space Sciences
P = Physical Sciences

Topic Outline



What is this topic about?

To keep it as simple as possible, (K.I.S.S. Principle) this topic covers:

Structure of the Earth

Review of Earth structure.

Moving Plates

The Theory of Plate Tectonics, including a little history.
Sea-floor spreading, subduction, mountain building.
The driving forces for the moving plates.

The Evidence

Some of the reasons we believe this theory is correct.

Tectonic Australia

Brief history of how the Australian continent was formed and what is happening now.

Tectonic Impacts

Effects of tectonic events on the Earth, on people and on other living things.

We begin with revision of some things covered before...

The Structure of the Earth

You already know that the Earth has a layered structure.

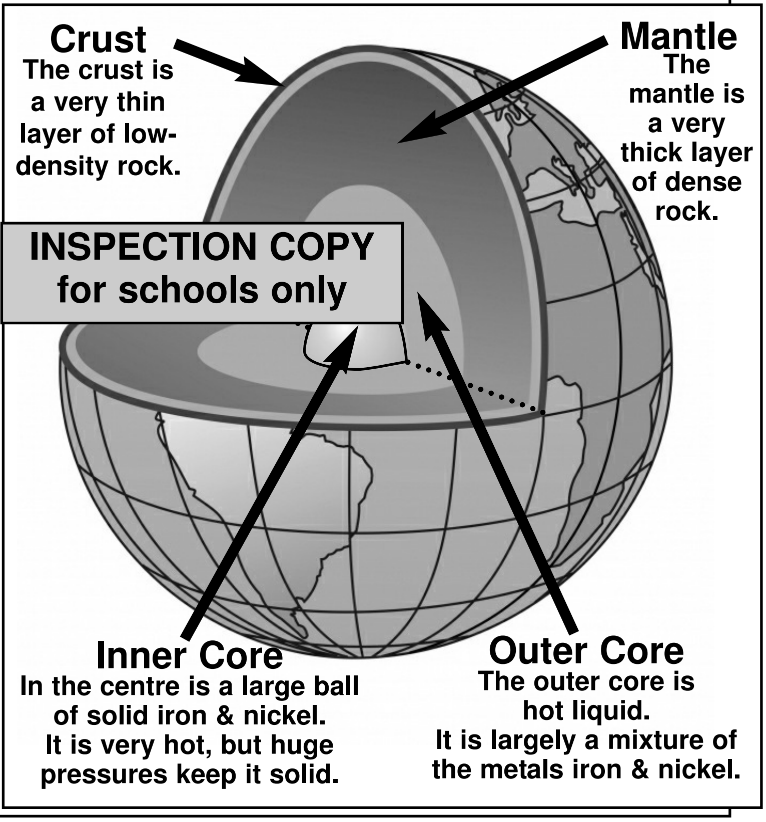
Inside the Solid Earth

Scientists have always been interested in earthquakes. By learning about earthquakes it was hoped that we might learn to predict them, and so avoid some of the deaths and destruction that they cause.

About 100 years ago, the study of earthquakes (called "Seismology") ("size-mol-ogee") became advanced enough that scientists began studying the way that earthquake shockwaves travel through the Earth.

From this, it became clear that the solid Earth is not totally solid, and has a layer structure, as shown.

Later, it was discovered that the outer layer is not a one-piece "shell", but is broken up into a dozen or so "plates" which slowly slide around on the layers underneath. As they slide, the plates move apart, or collide, creating earthquakes, mountain ranges, the ocean basins and even the continents themselves.



The Lithosphere

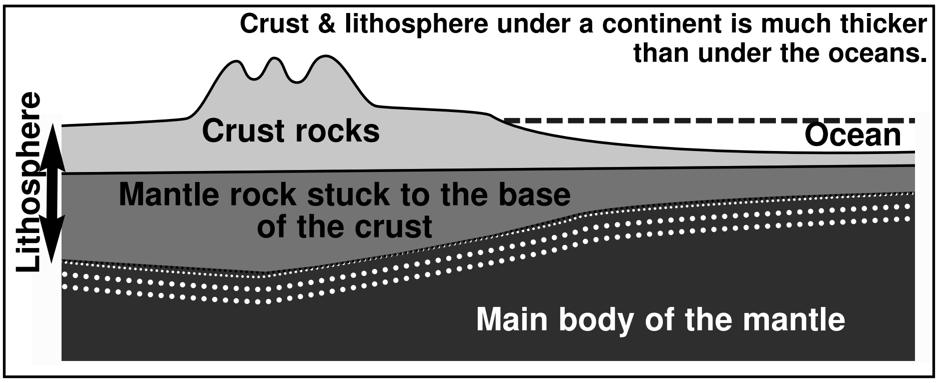
Although the Crust and Mantle are separate layers and have different density and composition, the boundary between them is not as simple and clear cut as the previous diagram suggests.

Attached to the bottom of the crust is a layer of mantle rock which has "welded" itself to the crust rocks above.

This 2-part layer is called the lithosphere.

The thickness of the lithosphere varies. Under the oceans, it can be about 5 km thick and is mostly crust rocks with very little mantle rock attached. Under the continents the lithosphere is over 100km thick.

100km of rock sounds like a lot, but compared to the 6,400 km diameter of the Earth, the lithosphere layer is an extremely thin shell on the outside.



Below the lithosphere is a "slippery layer" of the mantle. We now know that the lithosphere "floats" on the main body of the mantle, and is broken up into large pieces called tectonic plates.

The plates are pushed around by huge, relentless forces caused by heat energy upwelling from the Earth's Core.

In this topic you will learn about the tectonic plates and how they create and change the continents, oceans and mountain ranges over hundreds of millions of years.

Seismology

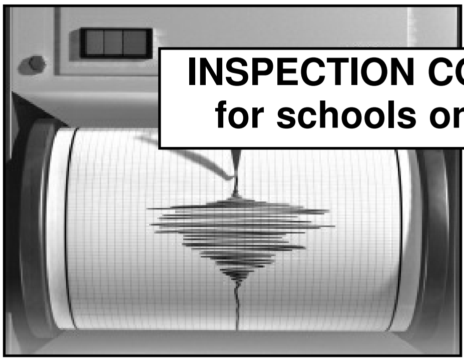
(Greek, "seismo"= shaking)

Seismology is the study of earthquakes and their shock waves.

Earthquakes

Earthquakes are caused by sudden movements in the Earth's crust. The sudden release of enormous energies sends out shock waves which radiate out from the "focus" of the 'quake.

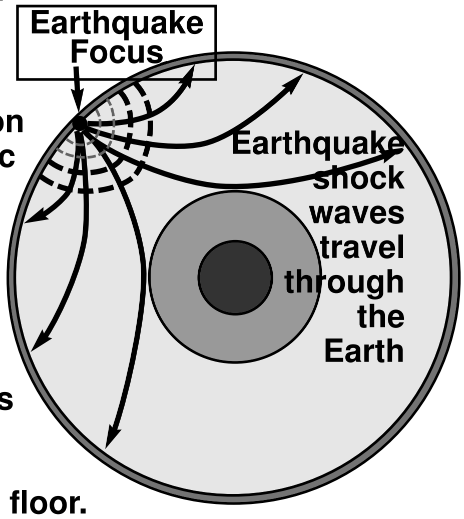
The shock waves are detected and recorded by a seismometer.



The photo shows an old-fashioned seismometer recording the vibrations on paper. Modern seismometers use electronic detectors and record data digitally for computer analysis.

Seismic Waves

The shock waves are refracted by different density rocks, and some types of waves cannot pass through the liquid Outer Core.



Our understanding of the structure of the Earth is based on studying the seismic waves and how they behave as they pass through the different layers.

There are thousands of seismometers all over the world, including the ocean floor. Most are automatic stations sending data to central computers by radio or phone links.

Many are warning systems to alert people to possible volcanic eruptions or tsunami waves in the oceans.

Locating an Earthquake

Within minutes of an earthquake occurring, modern seismometers can tell you exactly where it occurred. Here is a simplified explanation of how.

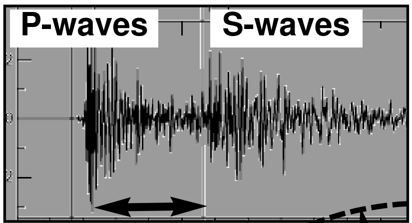
P and S Waves

Earthquakes give off several types of shock wave which have different properties and travel at different speeds.

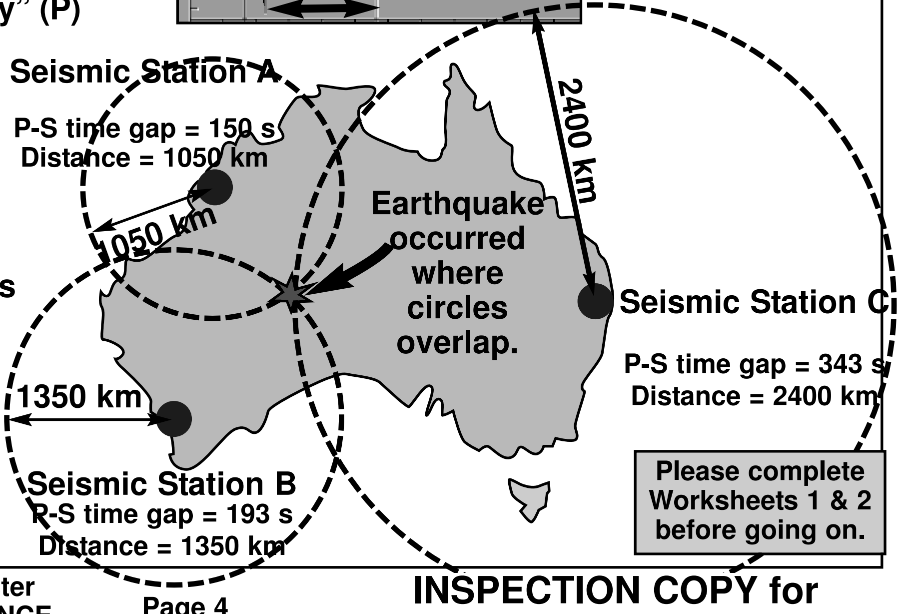
The fastest waves, called "Primary" (P) waves always arrive at a seismometer first, followed by "Secondary" (S) waves.

The time-gap between them gives the distance from seismometer to earthquake. Each 1.0 second P-S gap equates to a distance = 7 km.

If 3 or more seismometers record the earthquake, it can be located by triangulation. Study the diagram to get the idea.



Record of seismic shock waves, showing time gap (arrow) between S & P waves.



Please complete Worksheets 1 & 2 before going on.

A Little History: "Continental Drift"

As soon as accurate maps of the World appeared, some people noticed that the shapes of some of the continents fit together like jig-saw pieces. One man took this idea further.

Alfred Wegener

(German, 1880-1930) (pron: "vague-ner")

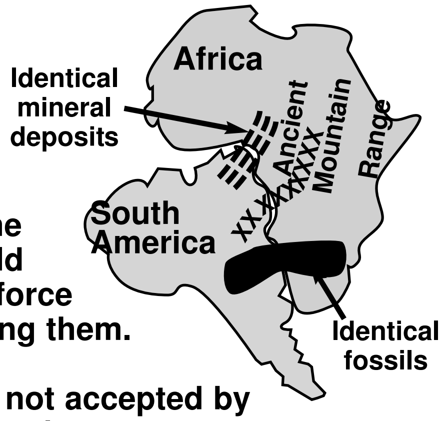
Wegener was trained in astronomy, but became interested in Earth Science.

Intrigued by the shapes of the continents, he studied the rocks and fossils on either side of the Atlantic Ocean.

He found many examples of identical, same-age minerals, fossils and geological features which are on separate continents, but in exactly the locations which fit the "jig-saw" idea.

In 1915, he published a theory of "Continental Drift" which proposed that the continents had once been joined together and had moved to their current locations.

He put forward a lot of geological evidence, but could not suggest how the continents could move, or what force might be pushing them.



His theory was not accepted by many other scientists.

Wegener died in a snow blizzard while doing climate research in Greenland.

New Technologies, New Evidence, New Theory

During World War II, sonar was developed for submarine warfare. In the 1950's it was used to accurately map the deep ocean floor for the first time. The demand for petroleum led to new techniques for deep-sea drilling from ships into the rocks under the sea. Sensitive "magnetometers" could be towed by a ship to map the magnetism in the rocks under the deep oceans. These new technologies led to new discoveries.

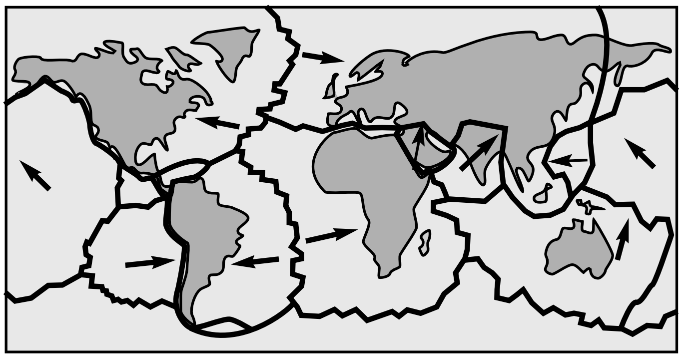
Plate Tectonic Theory

During the 1950's through 1970's a huge amount was learnt about the crust of the Earth, especially under the deep oceans.

New ocean-floor maps, magnetic data and rock samples from deep-sea drilling built up a body of evidence which showed that Wegener was right... the continents move!

Additional evidence came from seismology and studies of volcanoes. Details of the evidence will be presented later in this topic.

This led to a new theory called "Plate Tectonics". According to this theory, the lithosphere is not a simple "skin" like an egg shell, but is broken up into about a dozen pieces, or "plates".

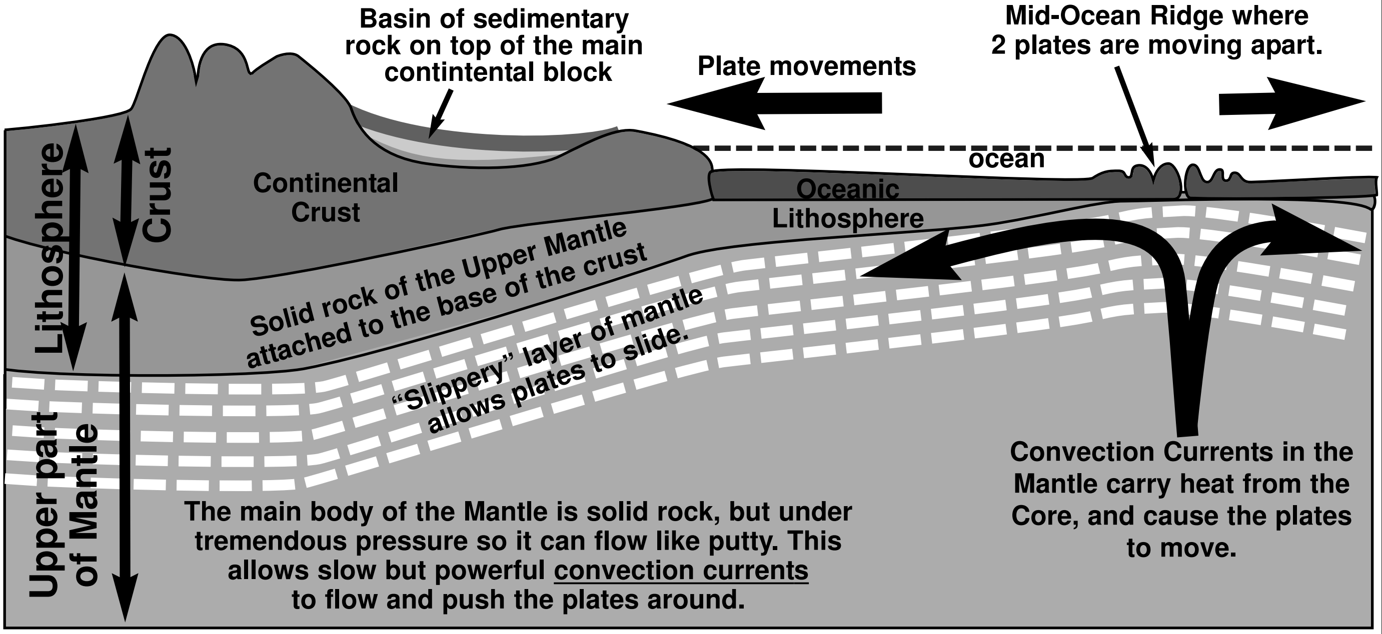


The plates slowly move around, sliding on the mantle layer below. Adjoining plates must either move apart, or crash together, or slide sideways past each other.

These movements cause earthquakes and volcanoes, create mountain ranges and volcanic islands and enlarge or destroy the ocean basins.

The Structure of a Tectonic Plate

Most of the major Tectonic Plates include a thick "block" of a continent plus a thin layer of lithosphere under an ocean. A few plates (such as the Pacific Plate) have no continent and are entirely made of lithosphere under an ocean.

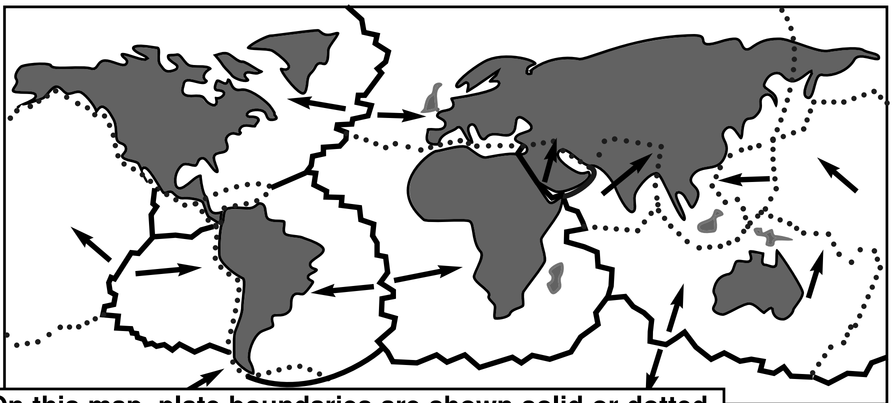


Each plate can slide sideways on a "slippery" layer of the Mantle. The movement is caused mainly by huge, slow convection currents which carry heat out from the Earth's core. The average rate of movement is about 5 cm per year, but movements are not slow and steady. Instead, the plate might not move at all for many years, then suddenly lurch forward by several metres.

It is these sudden movements which cause earthquakes. Plates have many cracks and fissures (faults) around the edges because the whole plate might not move all at once. As different sections lurch forward, the plate develops many cracks and offsets. Over millions of years, a plate not only moves sideways, but can rotate and/or change its shape.

When Plates Move Apart

When plates move away from each other, molten rock immediately billows up from underneath to fill the gap and create a new, thin layer of crust. This is occurring mainly on the floor of the oceans. Hidden deep underwater there are about 70,000 km of plate boundaries which frequently move (creating many small earthquakes) and erupt new oceanic crust.

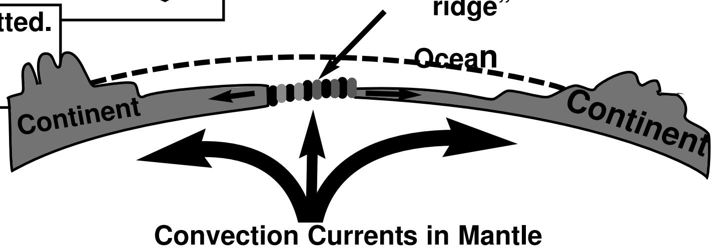


On this map, plate boundaries are shown solid or dotted. The solid boundaries are where plates are moving apart, mostly at the Mid-Ocean Ridges.

About 250 million years ago, the American continents were joined to Europe and Africa. As they have moved apart, the Atlantic Ocean has grown wider and wider by "sea-floor spreading".

SEA-FLOOR SPREADING

As plates move apart, new rock fills the gap, creating a "mid-ocean ridge"



The "Mid-Ocean Ridges" are chains of underwater mountains with a central "rift valley" where the plate edges are. In some places, such as Iceland, the eruption of new crust has built up high enough to reach the ocean surface, forming islands.

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When Plates Collide

The tectonic plates cover the surface of a sphere. If they are moving apart in some places, then they have to be colliding somewhere else. Exactly what happens in a collision zone depends on what type of lithosphere is involved.

Subduction

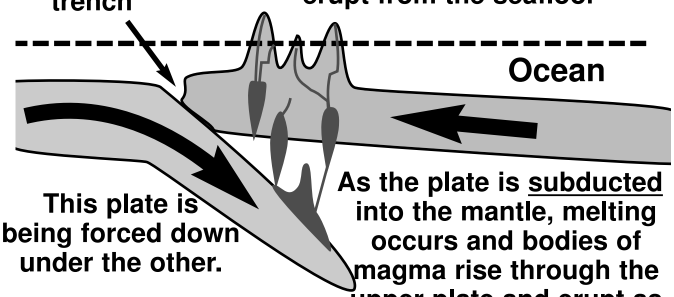
If one of the colliding plates is made of oceanic lithosphere it will be pushed down under the other plate and destroyed by being re-melted into the Mantle. This is called “Subduction”.

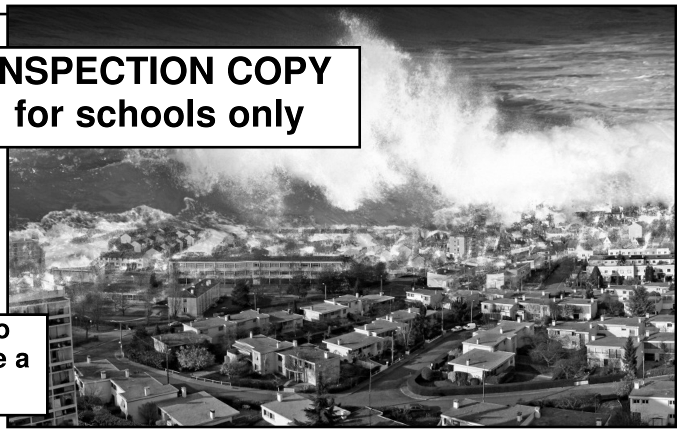
This type of collision is occurring north of Australia where the plate under the Pacific Ocean is being destroyed. The many volcanic islands of the western Pacific have formed in chains along the subduction zones. Deep ocean trenches occur where the plate is bent sharply downwards.

Each time a plate lurches forward, an earthquake occurs. Large under-sea ‘quakes can set off a tsunami, or seismic water wave, in the ocean. The Boxing-Day tsunami of 2004, which killed over 200,000 people, was caused by a ‘quake in the subduction zone north-west of Australia.

In March 2011, a huge earthquake near the coast of Japan (where the Pacific Plate is being subducted) set off a tsunami which devastated parts of Japan and killed thousands more.

Colliding Oceanic Plates





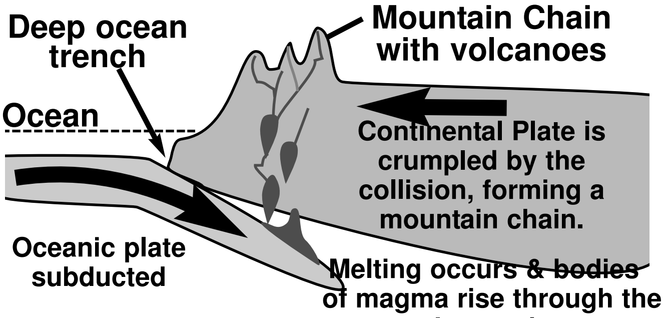
Composite photo of a ficticious tsunami about to destroy a coastal city. Real tsunamis are more like a “wall of water” rather than a giant surf wave.

If one of colliding plates is carrying a continent things happen differently. The crust rocks in a continent are too thick & low in density to be subducted.

The South American plate is colliding with the plate under the eastern Pacific Ocean. There are deep ocean trenches just off the coast and a massive mountain range (the Andes) along the western edge of the continent.

The mountains are formed by the “crumpling” of the continent’s crust in the collision. There are also many volcanoes and earthquakes.

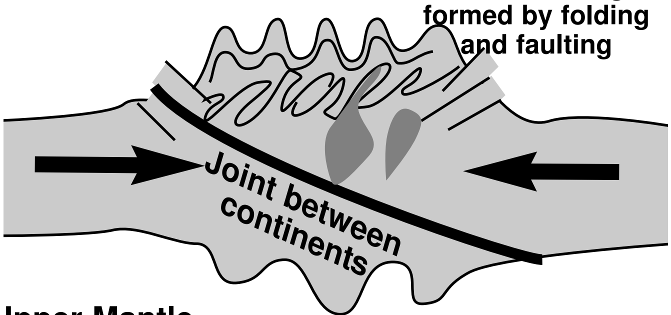
Oceanic-Continental Collision



Mountain Building

If both colliding plates carry the thick lithosphere of a continent, neither plate is subducted. Instead, the continents are crumpled by the collision. The crumpling effect folds and fractures the crust rocks and pushes them up to form a chain of mountains. The Himalaya mountains formed this way as the plate carrying India has collided with Asia. Rocks which were once under the sea are now 9 km high.

Continent - Continent Collision... NO SUBDUCTION



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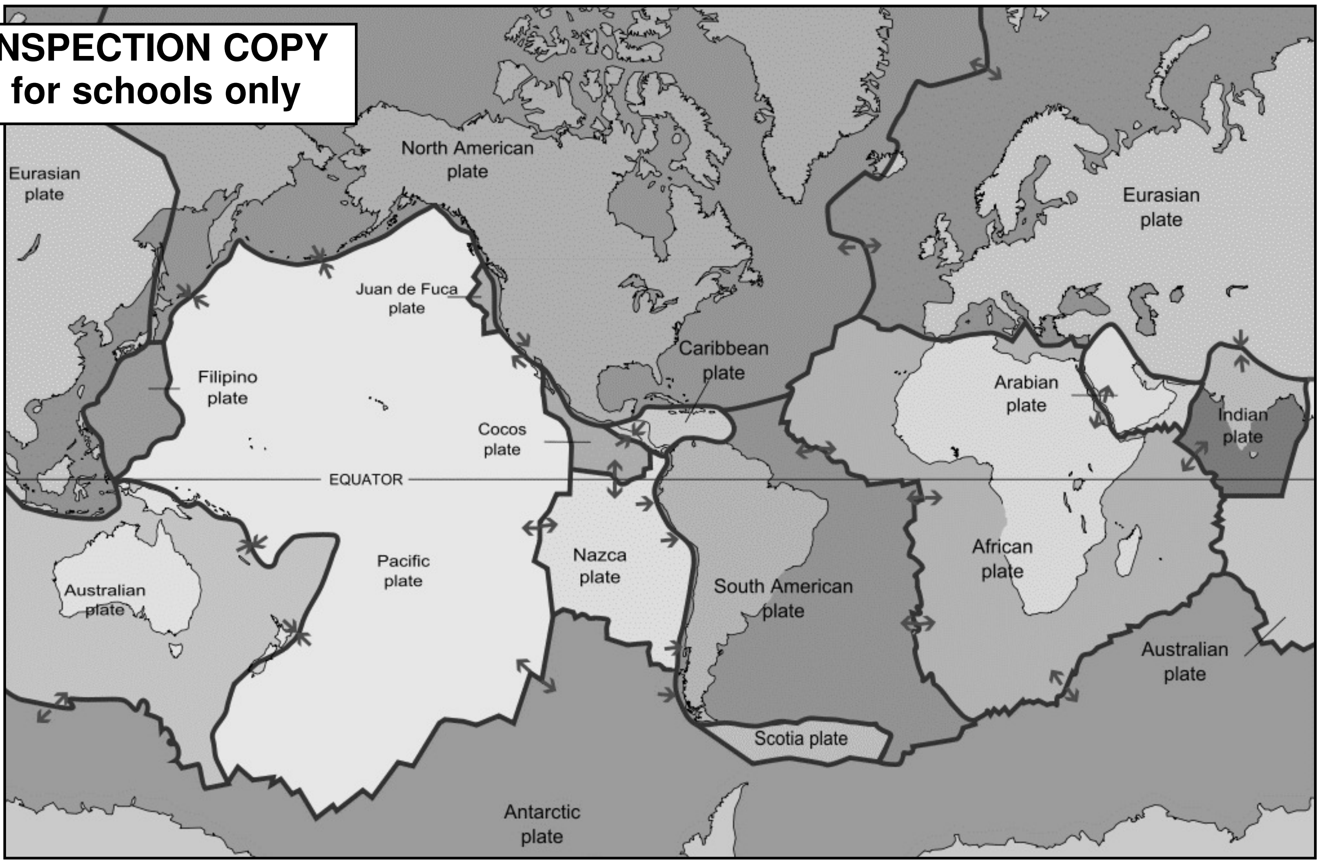
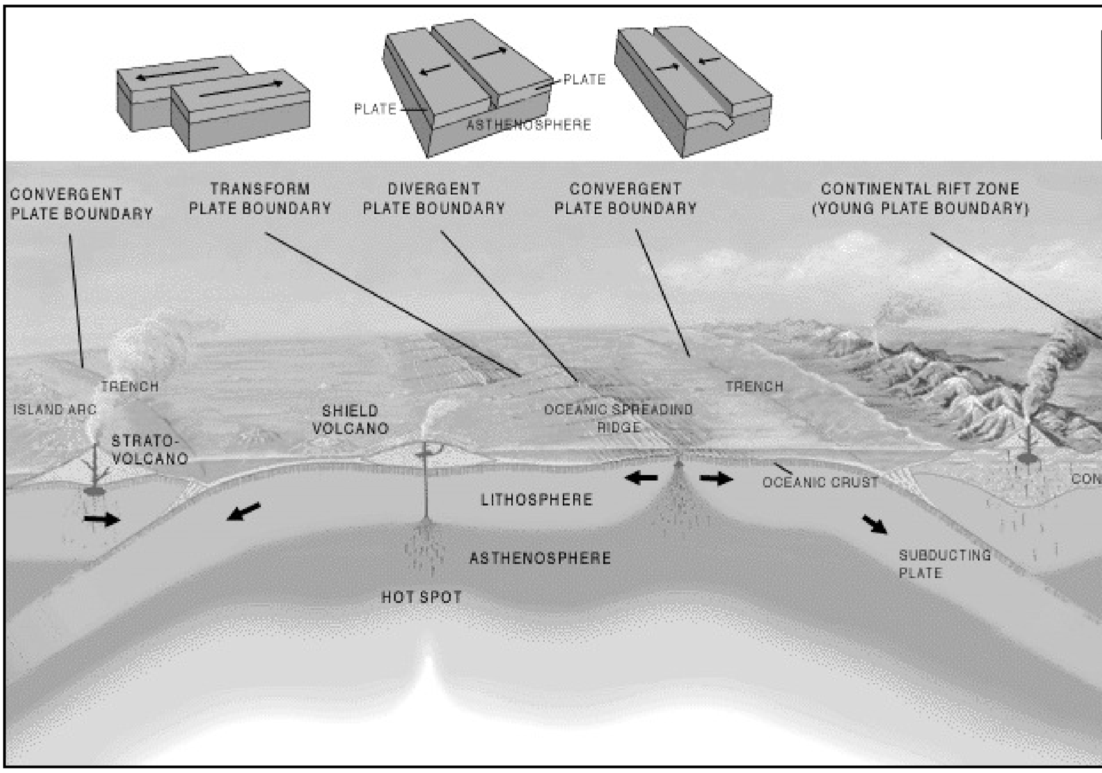
More Images

Study these for a greater understanding.



The diagram above is a more detailed and accurate map of the tectonic plates than the earlier sketches.
The diagram below shows all the types of plate boundaries at once.
Of course, there is no place on Earth exactly like this.

Please complete Worksheets 3 & 4 before going on.



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What Makes the Plates Move?

Each tectonic plate can be thousands of kilometers long and wide and 100 km thick. Made of solid rock, each plate weighs billions of billions of tonnes. What forces can make it move?

Convection Currents in the Mantle

We believe that the Earth's core is very hot due to the energy released from radioactive decay. It is so hot down in the core (around 6,000ºC) that the iron-nickel metal mixture should be completely molten. However, the immense pressure forces the Inner Core to be solid, despite the heat.

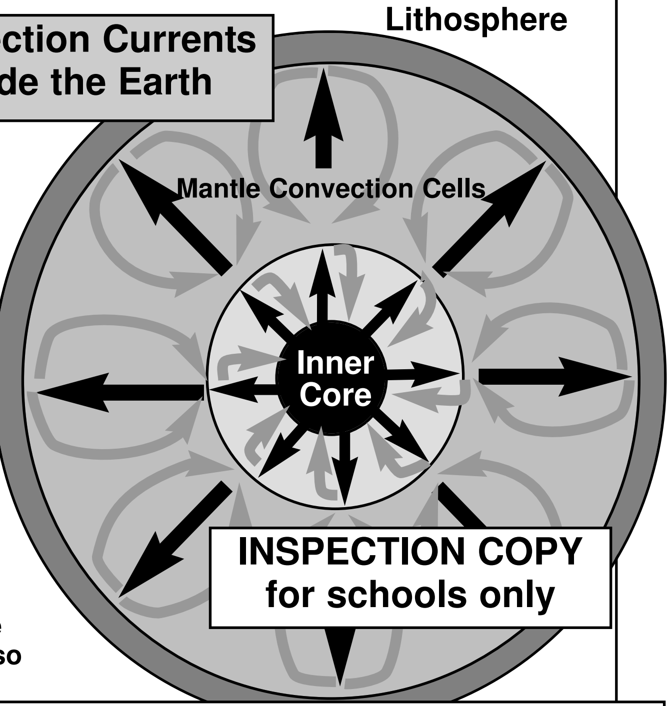
Since the outer core is liquid, convection currents flow in the liquid and carry the heat outwards.

This heat transfers into the mantle rocks. Although these are thought of as "solid" rock, the mantle is really a thick, semi-liquid. The immense heat and pressure forces the rock to flow like putty in huge convection "cells".

The flow is so slow that it takes many millions of years for the heat to flow from the core to the crust.

These huge, slow-flowing currents hit the base of the lithosphere and flow sideways. The currents drag on the bottom of the tectonic plates causing them to move. Mantle convection current are the "prime movers", but there are also other forces acting...

Convection Currents inside the Earth

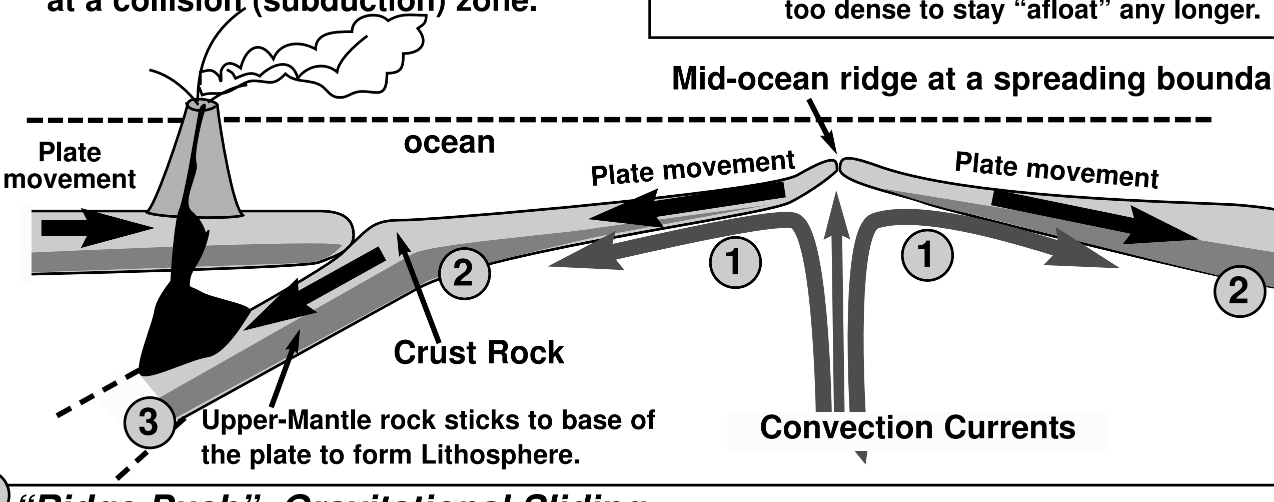


1 *"Convection Drag"*

As the convection currents reach the top of the mantle they flow sideways before cooling and descending again. Friction pulls on the plates, dragging them sideways.

3 *"Slab Pull"*

At a subduction zone, the descending plate is sinking into the mantle because of its high density. As it descends, it pulls the rest of the plate behind it. It is probably the increased density of an old oceanic plate which first fractures it and creates a new subduction zone. Density increases because mantle rock keeps solidifying onto the base of the plate. By the time an oceanic plate is "old" (about 200my) it may be too dense to stay "afloat" any longer.



2 *"Ridge Push" Gravitational Sliding*

When new crust material forms at the mid-ocean ridge it is only a relatively thin layer of crust rock. As the plate moves outwards from the ridge it becomes thicker because upper mantle rock solidifies onto the base to form complete "lithosphere". Its density increases, so the plate sinks lower into the underlying mantle. This causes the plate to slope like a dinner plate on a tilted table... gravity exerts a force which makes it slide sideways across the "slippery layer" underneath.
The "tilting" of plates is a fact... the sea floor at a Mid-Ocean Ridge can be several kilometres higher (closer to the sea surface) than the sea floor 500km away from the ridge.

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Evidence for Moving Plates

The Tectonic Plate Theory explains many things such as earthquakes & volcanoes, mountain ranges, island chains & deep ocean trenches. But is it really true? We believe it is true because there is a huge body of evidence to say so. Some evidence was noted by Alfred Wegener almost 100 years ago, but a lot was only discovered after the 1950's when new technologies allowed us to study the ocean floor, accurately measure the age of rocks and so on.

The Shape of the Continents

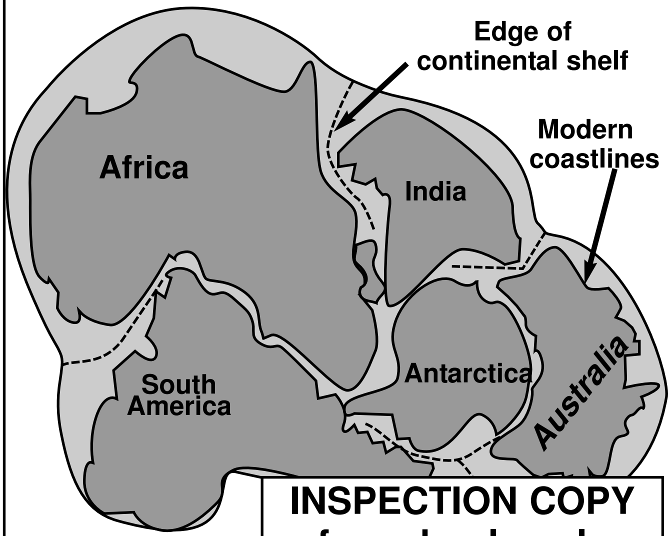
The continents of the Earth are like jig-saw puzzle pieces... they fit together quite well, especially along the lines of the "continental shelf" rather than the actual coastline.

The continental shelf is the true edge of each continent. In most cases it is under water today, but has been mapped using sonar.

When the continents are fitted together along their continental shelf margins, the fit is almost perfect.

This cannot be just coincidence! It strongly suggests that the modern continents were once joined together.

THE ANCIENT SOUTHERN CONTINENT GONDWANA



The Fossil & Mineral Evidence

Alfred Wegener discovered some of this evidence and used it to support his "Continental Drift" idea. Since his time, many more discoveries have been made of this same type of evidence.

Fossils

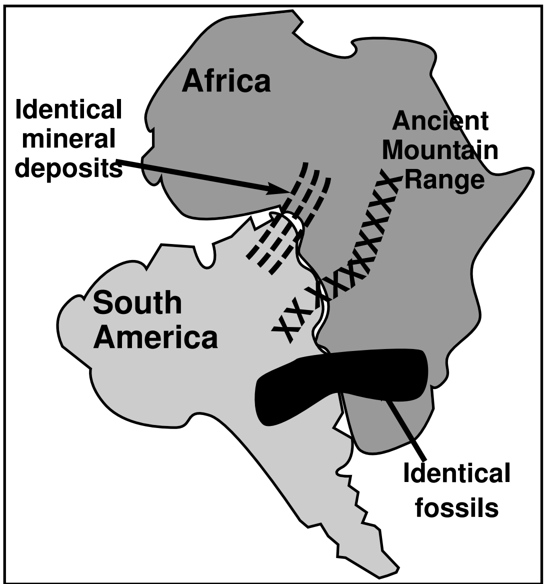
There are many examples of fossil plants and animals that are found on separate continents. These were land plants, or freshwater animals which could not have crossed an ocean.

The fossils are the same age, and identical specimens are found across (for example) Africa, South America, India, Australia and Antarctica. They must have evolved and lived right across an ancient continent. The moving plates later separated the fossil deposits.

Geological Evidence

There are many examples of rock layers and mineral deposits on different continents which are identical and are in locations which fit the "jig-saw" pattern.

Wegener noted evidence of the eroded "stump" of an ancient mountain range which is present in South America and Africa.



Scientists have even found scratch marks on rocks caused by ancient glaciers which gouged the rocks. The pattern of the scratches line up perfectly across what are now different continents. Of course, when the glaciers were doing the scratching, the continents were joined together.

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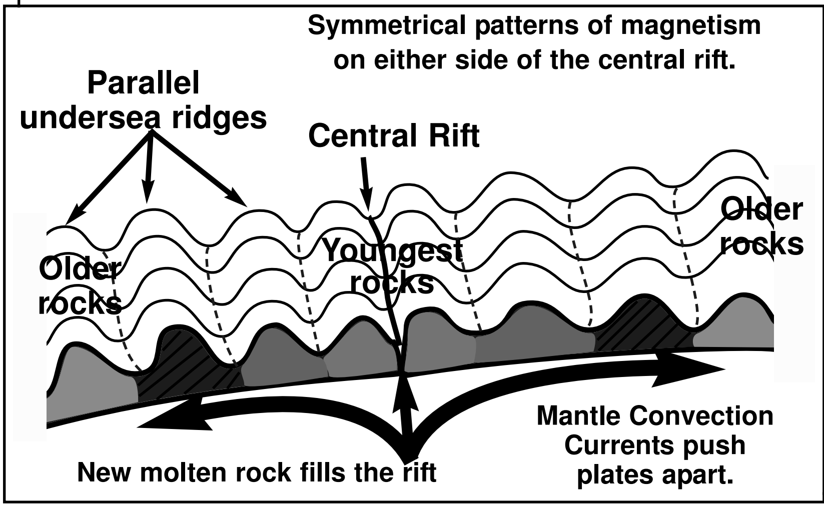
Evidence From the Ocean Floor

When scientists began mapping the ocean floor with sonar, they quickly discovered that there is a "Mid-Ocean Ridge" of underwater mountains running for 70,000 km through the world's oceans. New deep-water drilling equipment allowed rock samples to be collected, and new methods involving radio-activity allowed the age of rocks and sediments to be measured.
New magnetic equipment allowed the magnetism in the rocks to be measured accurately. The picture which emerged was clear evidence for the moving plates.

Mid-Ocean Ridges

The rocks of the parallel ridges are youngest in the middle and get progressively older as you move outward. The sediments which settle on top of the rock are thinnest at the mid-ocean ridge and get thicker as you move away from it.



The "residual magnetism" in the rocks (which was aligned as the rock hardened from molten lava) shows a symmetry on either side of the central ridge. Each matching band of magnetism represents a line of new rock formed as the crust plates moved apart.

Later, these bands were split and separated by even newer rock injected in the middle as the crust plates continued to be pushed apart.

While some rocks on the continents are billions of years old, the rocks of the oceanic crust are all relatively young. This is because oceanic crust is created where plates move apart, and then destroyed again by subduction within a few hundred million years. There is no really ancient rock under the oceans.

Please complete Worksheets 5 & 6 before going on.

Evidence From Seismology

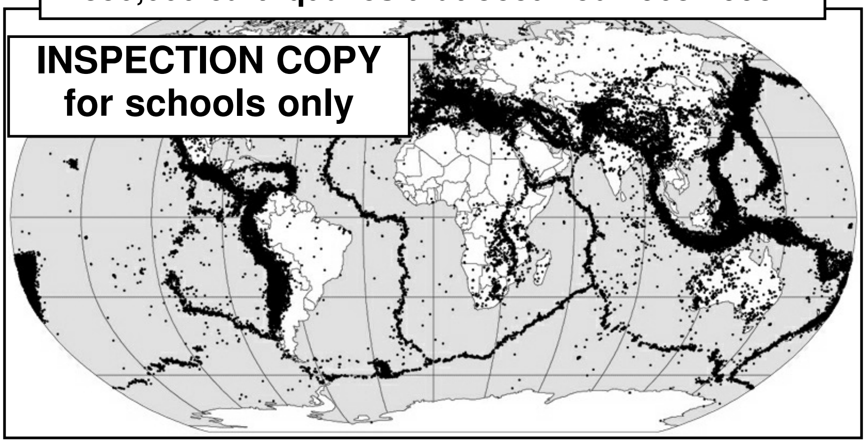
Even several hundred years ago, it was realised that earthquakes and volcanic eruptions occur most often in certain "active zones", such as the edge of the Pacific Ocean which is called the "Pacific Ring of Fire".

When data from modern seismology is analysed a clear pattern emerges.

The vast majority of earthquakes (and volcanoes) are located along the boundaries of the tectonic plates.

On this map you can clearly see the line of the mid-ocean ridges and the heavy concentration of earthquakes where the plates are colliding.

Each dot on this map is the focus of one of the 350,000 earthquakes that occurred 1963-1998.



Notice that, while Australia has relatively few earthquakes, there is a very active region to our north. In 2004 and 2011, massive earthquakes in this region caused tsunamis.

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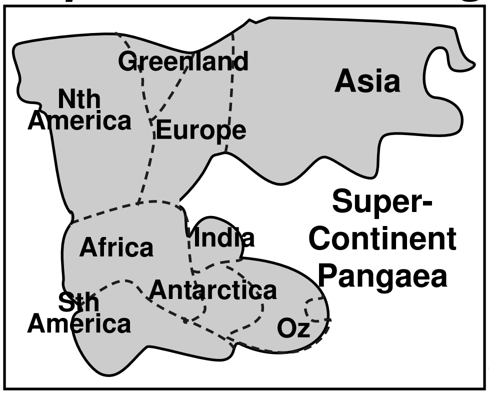
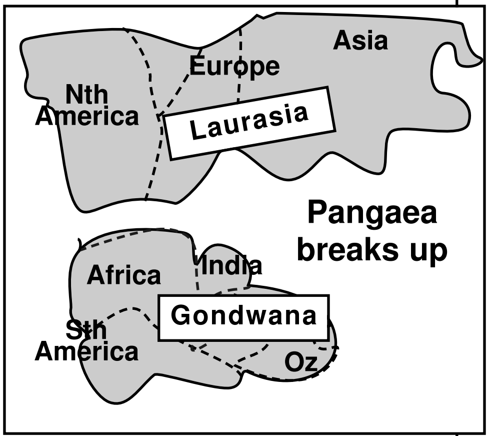
A Changing Map of the World

Supercontinent Pangaea

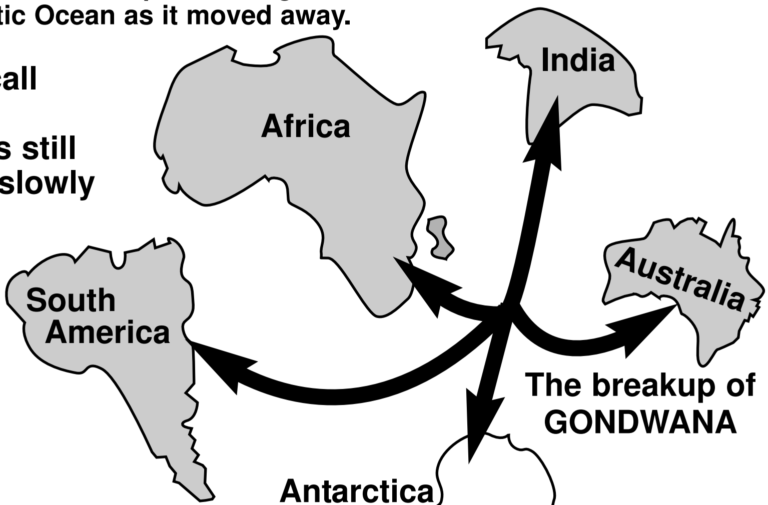


The evidence indicates that 200 million years ago, all the continents were joined together in one “super-continent” called Pangaea, which means “whole Earth”.



About 180 million years ago, Pangaea split into 2 parts as shown. Later, North America separated from Europe, creating the Atlantic Ocean as it moved away.

In the south, the ancient continent we call Gondwana also began breaking up.
Until 45 million years ago Australia was still joined to Antarctica. Today Australia is slowly moving north.

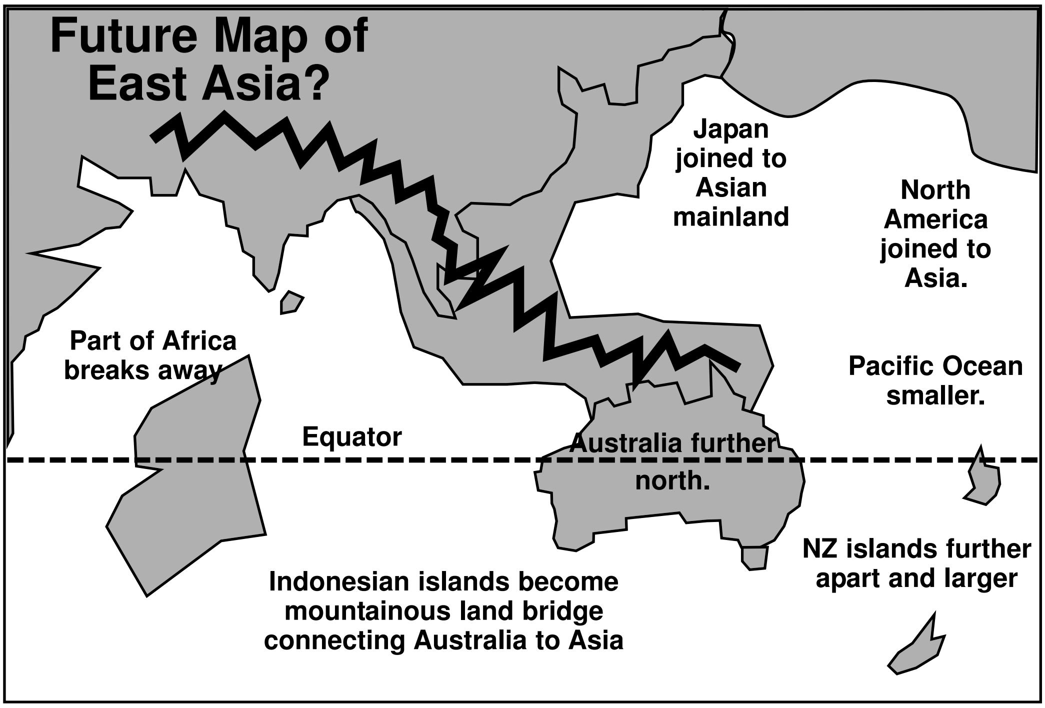


If all the tectonic plates keep moving the way they are now (no guarantees!) we can predict what the world might look like in 100 million years time:

Africa will join completely onto Europe, destroying the Mediterranean Sea.

The eastern one-third of Africa will split-off to form a separate continent.

North America will connect to Asia and the north Pacific Ocean will shrink.



Eventually, all the continents may collide and join together to form a new “super-continent” like Pangaea, but with all the parts in different places. The new supercontinent might later crack up into new fragments.

This cycle has occurred over and over in the past. Western Australia was once joined to Canada in a previous super-continent long before Pangaea was formed.

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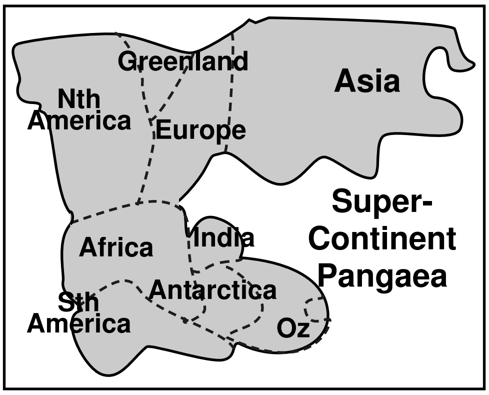
Evolution of the Continents

Supercontinents & Supercycles

We now know that all the modern continents were once joined together in one "supercontinent" called Pangaea (= "whole Earth"). The rest of the Earth was covered with a global ocean called Panthalassa (= "whole ocean").

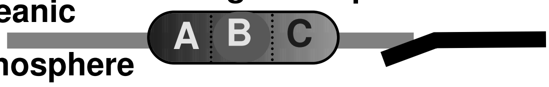


But how did Pangaea form in the first place?

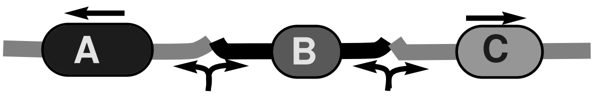
It is thought that Pangaea formed from the collisions of previously separate continents. Those previous continents were totally different to the modern ones.

Those pre-Pangaea continents are thought to have come from the breakup of another previous supercontinent, and so on... a continuous cycle of forming and breaking up of supercontinents... a "supercycle" of Plate Tectonics.

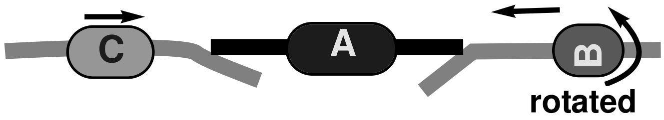
1. Oceanic Lithosphere — Original Supercontinent



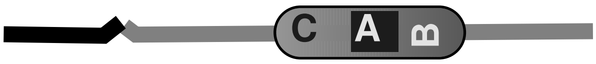
2. Supercontinent splits apart. Sea-floor spreading creates new oceans as continents move apart.



3. Eventually, continents approach each other again... possibly on the other side of the world. Subduction shrinks the old, previous oceans, until the continents collide.



4. New Supercontinent forms

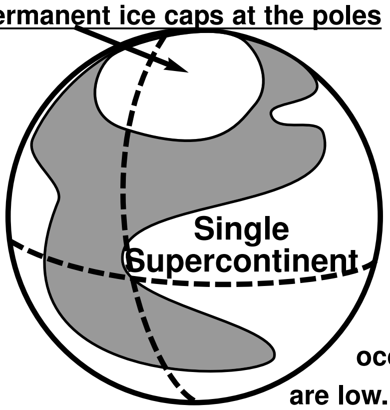


The entire "supercycle" is thought to take approximately 400-500my and has major impacts on global climate.

Global Climate & Plate Tectonics

As scientists have gathered information about ancient plate movements and the "continental supercycle" they have noticed an interesting general correlation with global climate.

Permanent ice caps at the poles

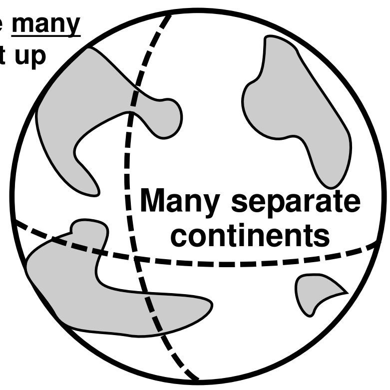


When there is a single supercontinent, the world climate is colder and drier, with lower sea levels.

This is because volcanic activity is at a minimum (less rifting and subduction occurring) and CO_2 levels are low. A reduced greenhouse effect lowers the average world temperature.

Low temperature means less evaporation, and lower rainfall. Formation of a permanent ice-cap lowers sea levels for many millions of years. The world becomes cold & dry.

When there are many continents split up all over, there must be more rifting and subduction going on, and so volcanic activity increases CO_2 levels.



The Greenhouse Effect increases global temperatures, so there is more evaporation and more rainfall. Unless a continent drifts over a pole it is unlikely there are ice caps, so sea levels are higher.
At the moment, we are somewhere in-between these situations.

There is evidence that our ice-caps are melting. If they melted completely, sea-levels would rise by 60m or more.

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Tectonic History of Australia

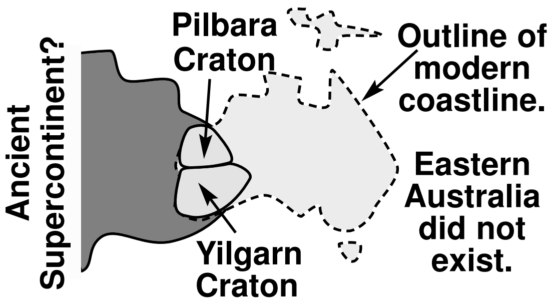
Cratons

A “craton” is a mass of continental rock which is ancient & stable. A craton rarely seems to be broken up by tectonic movements, probably because it is too thick. It is a chunk of lithosphere which has survived many “supercycles” and been part of many “supercontinents”, but still manages to stay in one piece.

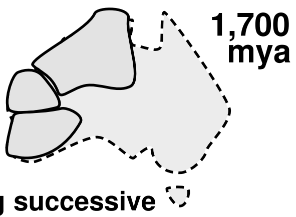
Australia contains some of the oldest cratons on Earth. Parts of Western Australia have probably been through many continental supercycles, although we have little knowledge of events more than 2 cycles back.

Evolution of the Australian Continent

1.



The diagram above shows the most ancient part of Australia that we know about. The Pilbara and Yilgarn Cratons were already ancient when they joined together about 2,300 mya, possibly as part of the formation of a new supercontinent.



Over the following billion years, several younger cratons were added to the east to make a larger, stable continental mass. Presumably, these additions occurred during successive periods of collisions to form new supercontinents.

2.

We know that Australia’s cratons were once connected to cratons found today in Canada.

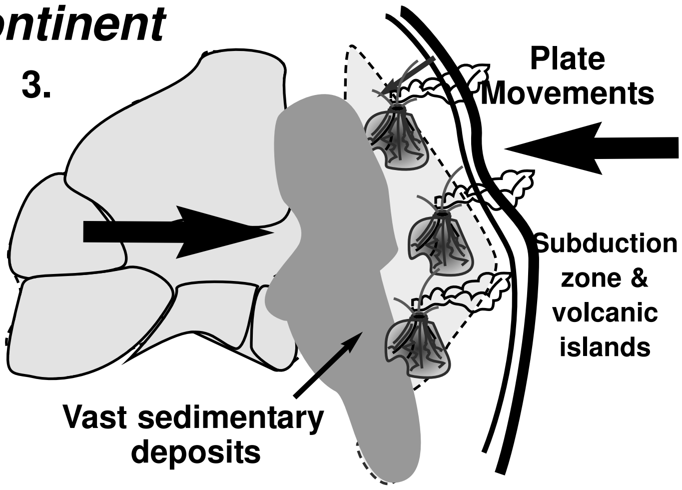
The supercontinent prior to Pangaea, “Rodinia”, is thought to have formed before 700 mya. It began to break up again about 600 mya, but the Australian cratons remained together.

As supercontinent “Rodinia” broke up, the area that is now the eastern states of QLD, NSW, Vic and Tassie became a collision zone.

By 500mya, the Australian cratons were colliding with another plate, so that a subduction zone formed.

By 400mya, volcanic island arcs erupted from the sea floor. Huge amounts of sediments were deposited in the shallowing sea, from erosion of the continent and islands. (diagram 3, above right)

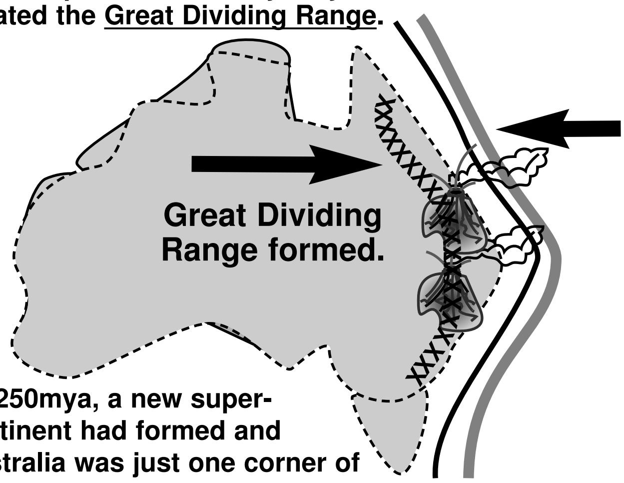
3.



Sea levels were higher than today, so many areas of the continent were under shallow seas.

Vast sedimentary deposits formed in eastern Australia, including the great coal seams of QLD, NSW & Victoria, and the great “Hawkesbury” sandstone deposits around Sydney. The collision also created the Great Dividing Range.

4.



By 250mya, a new supercontinent had formed and Australia was just one corner of “Pangaea”.

Later, Pangaea broke apart. Later still, the southern portion “Gondwana” split up as described earlier.

For the past 200 million years or so, Australia has been a very quiet place tectonically. The main geological process operating has been erosion, so our land is broad and flat. Sediment washed from the mountains has formed the coastal plains where most Australians live.

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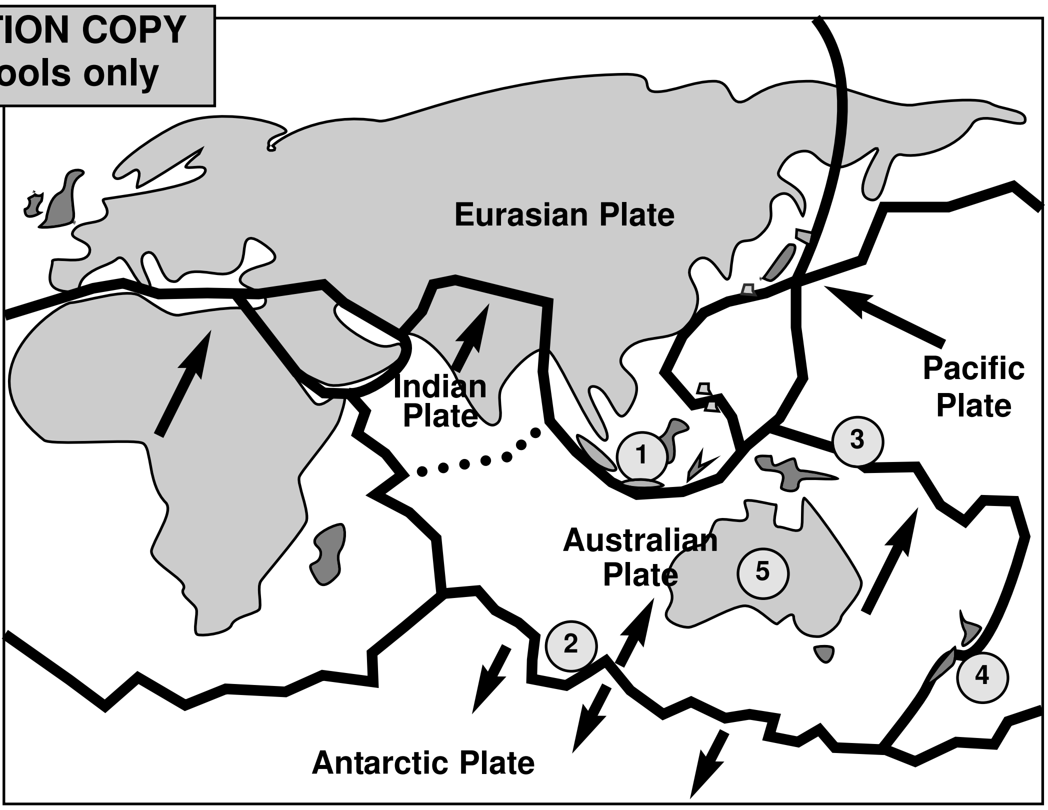
Tectonic Australia Today

Australia seems to be a very quiet place in terms of tectonic activity. We have no volcanoes and only a few, mostly small, earthquakes. Why?

The Australian Plate

The diagram shows the approximate position of the "Australian Plate" and its neighbours. The arrows show the plate movements.



1 Indonesia

Many active volcanoes. Earthquakes are common. On Boxing Day 2004, an under-sea 'quake made a tsunami which killed an estimated 200,000 people. This is a Subduction Zone.

2 Southern Ocean Floor

Mapping of the ocean floor reveals a Mid-Ocean Ridge with many small earthquakes. Sea-Floor Spreading is pushing Australia and Antarctica further apart.

3 Pacific Island Chains

Look at a map of this region. There are many Deep Ocean Trenches and hundreds of Volcanic Islands. Another Subduction Zone.

4 New Zealand

They aren't called the "Shakey Isles" for nothing! Many earthquakes & active volcanoes. NZ sits on the edge of our plate where it slides sideways past the Pacific Plate.

Please complete Worksheet 7 before going on.

5 Australia

We are surrounded by tectonic activity, but we experience almost none. That's because we are in the quiet centre of our tectonic plate. All the exciting, but dangerous and violent things happen at the edges where 2 plates meet.

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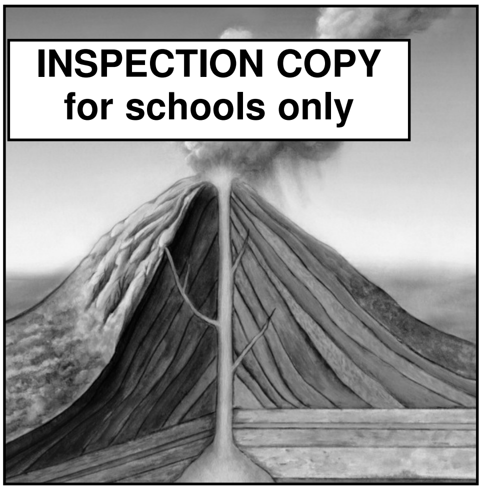
Impacts of Tectonic Events

What effects do the movements of Tectonic Plates have on people & on the Earth?

Effects of Volcanoes on Earth Climate

Volcanic Eruptions

Volcanic Eruptions release huge amounts of gases, ash and dust. Most of the solid particles fall quickly and blanket the surrounding area, but some fine particles can be injected into the high atmosphere and remain there for years.



These fine particles reflect light & heat from the Sun. This has a cooling effect which can last for years.

Volcanoes release a lot of acidic gases such as sulfur dioxide. This can cause "acid rain" which damages ecosystems.

CO_2 and Greenhouse

Although fine dust particles can have a short-term cooling effect, the longer-term effect of volcanoes can be the opposite.

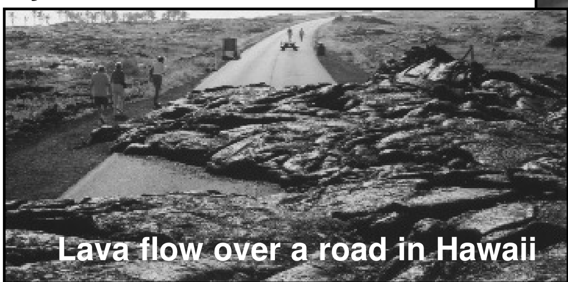
Volcanic eruptions release huge amounts of CO_2 gas. This is a "greenhouse gas" which traps heat which would otherwise radiate back into space. This has the effect of raising global temperatures.

One volcano has little impact, but there have been times in the Earth's history when widespread activity caused major climate changes. We believe that, about 250 million years ago, 95% of all life on Earth became extinct. The cause seems to have been sudden climate changes due to huge volcanic eruptions which first cooled, then heated the Earth.

Volcanoes & People

Lava Flows

When people think of volcanic eruptions, they usually think of lava. Although a lava flow can destroy property, it is seldom a danger to people. The big killers are "Pyroclastic Flows" and "Lahars".

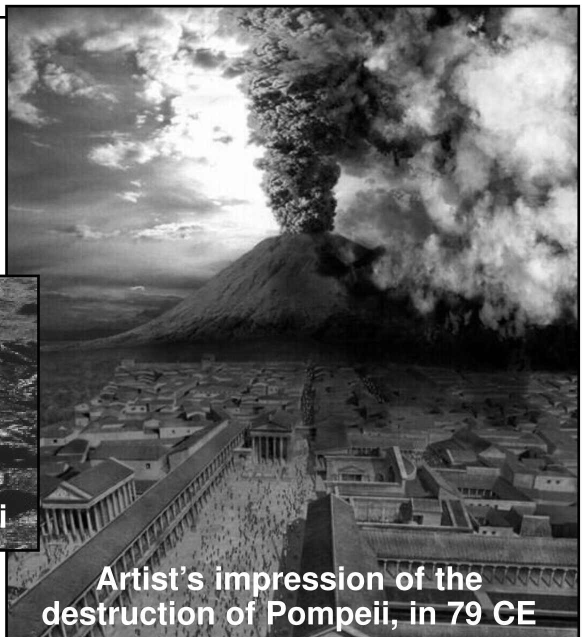


Lava flow over a road in Hawaii

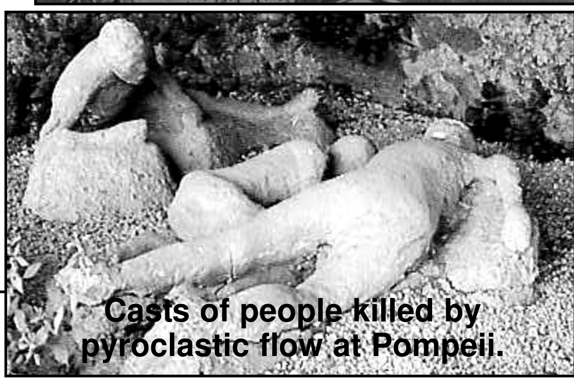
Pyroclastic Flow is a cloud of red-hot ash and poisonous gases which can pour down a volcano at 100km/hr. Nothing survives.

Lahar is a flow of mud, ash, water and debris from a melted glacier or burst lake on a volcano. Lahars simply bury everything in their path.

Despite these dangers, people have chosen to live near volcanoes throughout history because the soil is usually fertile and excellent for farming.



Artist's impression of the destruction of Pompeii, in 79 CE

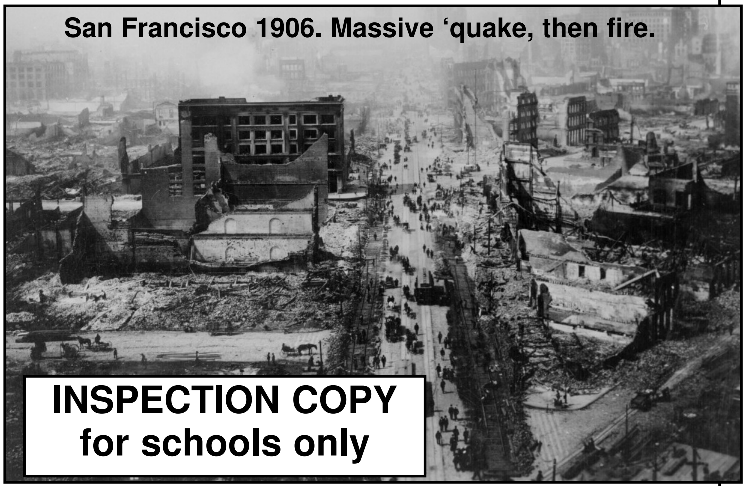


Casts of people killed by pyroclastic flow at Pompeii.

INSPECTION COPY for schools only

Earthquakes & People

In a severe earthquake the ground heaves so that you cannot stand upright. However, this ground motion is not the main hazard to people. The big killers in any earthquake are collapsing structures, fires & tsunamis.


San Francisco 1906. Massive 'quake, then fire.

When major earthquakes hit large cities, the death toll can be enormous. Most casualties result from collapsing buildings. Multi-storey apartment blocks can "concertina" downwards: each floor is a block of concrete which can fall onto the next in a downward "domino effect".

Knowing the danger, many people rush out into the streets and are then showered with falling roof tiles and broken glass from buildings that have not collapsed, but are shaking violently.

As the ground moves, pipes carrying water, power & gas are ruptured. Fires break out, & broken water mains make it difficult to fight the blaze. In the great San Francisco earthquake of 1906 large areas of the city survived the 'quake but were destroyed by uncontrollable fires.

In hilly or mountainous areas, earthquakes can trigger landslides which can bury entire villages. When the earthquake occurs under the sea, the crust movements can cause destructive water waves called "tsunamis". In recent years there have been 2 major tsunamis in the Asian region.

Indonesia, Boxing Day 2004

A massive undersea earthquake in the subduction zone near Sumatra, Indonesia set off a tsunami which killed about 200,000 people in Indonesia, Thailand, Malaysia, Sri Lanka and other nations around the Indian Ocean.

In many places there was no warning before a wall of water wiped out entire towns, beach resorts and rural farming communities.


A tourist took this photo as the 2004 Asian Tsunami hit the coast of Thailand. Moments later, most of these people died.

Japan, March 2011

One of the largest earthquakes ever recorded occurred in the subduction zone just off the Japanese east coast. There was considerable earthquake damage, then within an hour a 30m tsunami washed up to 10km inland. About 15,000 people died. This death toll was considered to be quite low due to Japan having excellent building codes, warning systems, tsunami defences and emergency refuges.


The day after the tsunami:
Sendai International Airport, Japan

Despite all defences, the tsunami damaged the Fukushima Nuclear Power Plant. This led to a later explosion and leakage of radioactivity from the reactors.

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Impacts of Tectonic Events (cont.)

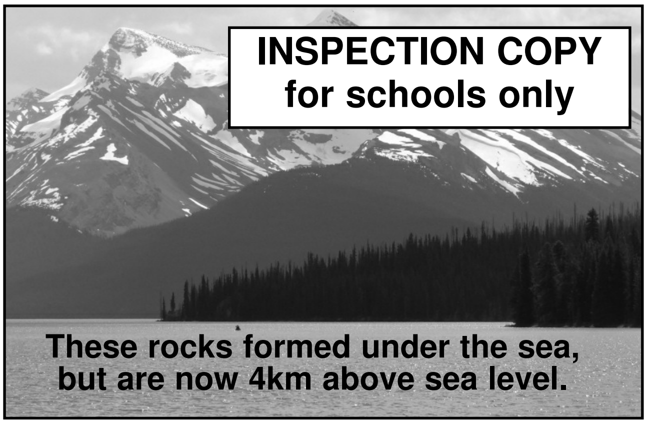
Effects on World Geography

Over hundreds of millions of years, the moving plates totally change the size and arrangements of the continents and the oceans. As the oceans change, so do the ocean currents. This has major impacts on the Earth's climate and on plants & animals.

Sea-Floor Spreading

Where plates move apart, new crust is created at the mid-ocean ridges. This widens the ocean basins.

200 million years ago, the Atlantic Ocean did not exist because North America was joined to Europe. As the lithosphere fractured into separate plates which moved apart, the Atlantic Ocean was created, and is still growing wider.



These rocks formed under the sea, but are now 4km above sea level.

Mountain Building

Mountain chains are formed where plates collide. The crust is buckled, folded and faulted.

Earthquakes thrust the crust upwards to form the great mountain chains of the world. Erosion then forms valleys and plains. All our landscapes result.

Subduction

Subduction destroys oceanic lithosphere and shrinks oceans. Near subduction zones, volcanic islands grow from the ocean floor. The Pacific Ocean is shrinking as Nth America approaches Asia.

Metamorphism

The high temperatures and pressures caused by tectonic forces changes the rocks themselves. Shale turns to slate, and limestone becomes marble.

Please complete Worksheet 8.

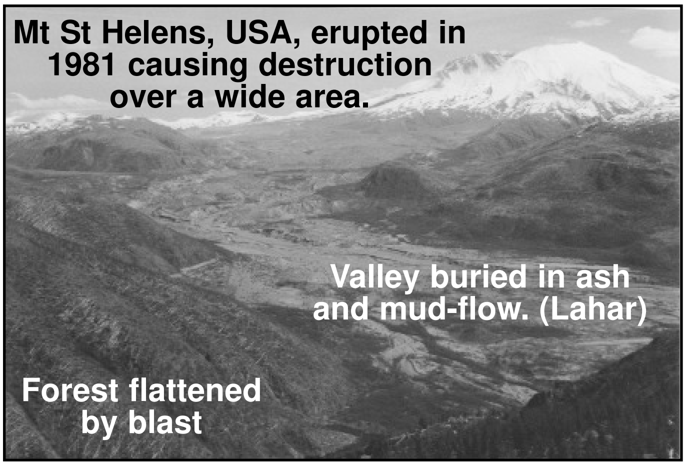
Effects on Living Things

We tend to think that earthquakes and volcanic eruptions always cause destruction of ecosystems and death of living things. However, there is a positive side as well.

Mass Extinctions

At a local level, a tsunami can destroy coral reefs or coastal mangrove ecosystems. A volcano can destroy forests, or bury entire ecosystems under hot ash. Locally, the living communities can be devasted.

It can also be global. It was already mentioned that volcanic activity almost completely wiped out life on Earth by causing huge climate change about 250mya.



Mt St Helens, USA, erupted in 1981 causing destruction over a wide area.

However, we know from the fossil record that after every mass extinction, life always "bounces back" with greater variety and numbers than before.

New Habitats

Tectonic events create new places to live. For example, coral reefs thrive around volcanic islands created by subduction zones. Many new species evolve on the islands themselves.

Mountain ranges and the rivers, valleys and plains that form from them, all become habitats for living things.

Recycling Chemicals

Ancient farmers knew that volcanoes create fertile soil. An eruption can destroy, but fresh lava brings minerals which fertilise the soil.

Globally, plate tectonics is essential for cycling vital chemicals, such as carbon, calcium and phosphorus. Scientists now realise that without tectonic activity, the Earth's biosphere could not evolve and thrive as it has done.