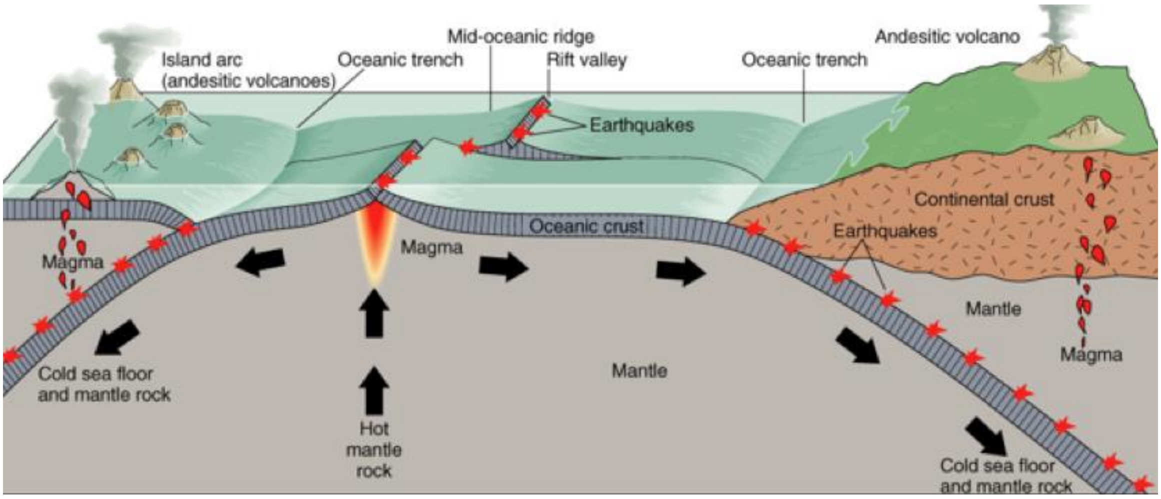
GEOGRAPHY
A Level

AS Unit 1
Section B

Tectonic Hazards



A. Prickett
Barry Comprehensive School

Section B: Tectonic Hazards

Focus	Geographical content	Revision
1.3.1 Tectonic processes and hazards	• Characteristics of the Earth's structure including core, mantle and crust and the boundaries between them. • Mechanisms of plate movement including internal heating within the Earth, convection currents, ridge push and slab pull. • Plate distribution and the processes operating at different margins including diverging, converging and conservative margins; and tectonic activity at hot spots. • Global distribution of tectonic hazards and their link to tectonic processes. • Characteristics of the physical hazard profile that influence its impact including magnitude (as measured on Mercalli and Richter scales and Volcanic Explosivity Index (VEI), predictability, frequency, duration, speed of onset and areal extent.	
1.3.2 Volcanoes, processes, hazards and their impacts	• Types of volcano including shield, composite and cinder and types of volcanic eruption including explosive and effusive. • Volcanic processes and the production of associated hazards including pyroclastic flows, lava flows, ash falls, lahars, jökulhlaups, volcanic landslides and toxic gases. • Demographic, economic and social impacts of volcanic hazards on people and the built environment including primary and secondary effects. • Local scale, regional scale and global scale impacts of volcanic activity. • Use example of one eruption to demonstrate the varied degree of risk and impacts of volcanic activity.	
1.3.3 Earthquakes, processes, hazards and their impacts	• Earthquake characteristics to include P and S waves, focus, depth and epicentre. • Earthquake processes and the production of associated hazards including ground shaking, liquefaction and landslides. • Demographic, economic and social impacts of earthquake activity on people and the built environment including primary and secondary effects. • Local scale, regional scale and global scale impacts of earthquake activity. • Use example of one place specific event to demonstrate the varied degree of risk and impacts of earthquake activity.	
1.3.4 Human factors affecting risk and vulnerability	• Economic factors including level of development and level of technology. • Social factors including the population density, population profile (age, gender) and levels of education. • Political factors including the quality of governance. • Geographical factors including rural / urban location, time of day and degree of isolation.	
1.3.5 Responses to tectonic hazards	• Monitoring, predicting and warnings of volcanic eruptions and earthquakes. • Short-term and long-term responses to the effects of earthquake and volcanic hazards (the hazard management cycle).	

INTRODUCTION

What are Natural Hazards?

Most area of the world suffer from **NATURAL EVENTS**, which result from natural processes within the environment. Such events are beyond our control and we can't do anything to stop them occurring. E.g. flooding, earthquakes, volcanoes, hurricanes, drought etc.

A natural event only becomes a **NATURAL HAZARD** when it **threatens people**, causing damage to property, buildings, infrastructure and often loss of life. (A dictionary definition of a hazard = "a situation with a potential to cause harm")

Some parts of the world are more vulnerable to natural hazards than others and so are considered as **high risk areas**. With the rapid growth of population in the world, more and more people are becoming affected by natural hazards and so the **hazard potential is increasing**. As a result, the 1990's have been referred to as "The Disaster Decade" during which the United Nations (UN) established UNDRO (United Nations Disaster Relief Organisation). UNDRO is based in Geneva and coordinates many organisations involved in disaster relief.

What are Tectonic Hazards?

Both **volcanoes and earthquakes** are **TECTONIC HAZARDS**. This means that they are due to plate movement (plate tectonics). Their cause lies **within** the earth and they are also known as **ENDOGENETIC** hazards. (Weather or climatic hazards are called ECTOGENETIC as their cause is outside the earth).

Tsunamis are also tectonic hazards. These are huge tidal waves caused by an underwater earthquake or volcano.

About 3,000 earthquakes occur every year, but only about ten or so are considered as serious natural hazards. Only about 50 volcanic eruptions occur every year, and on average are only about 10% as damaging as earthquakes.

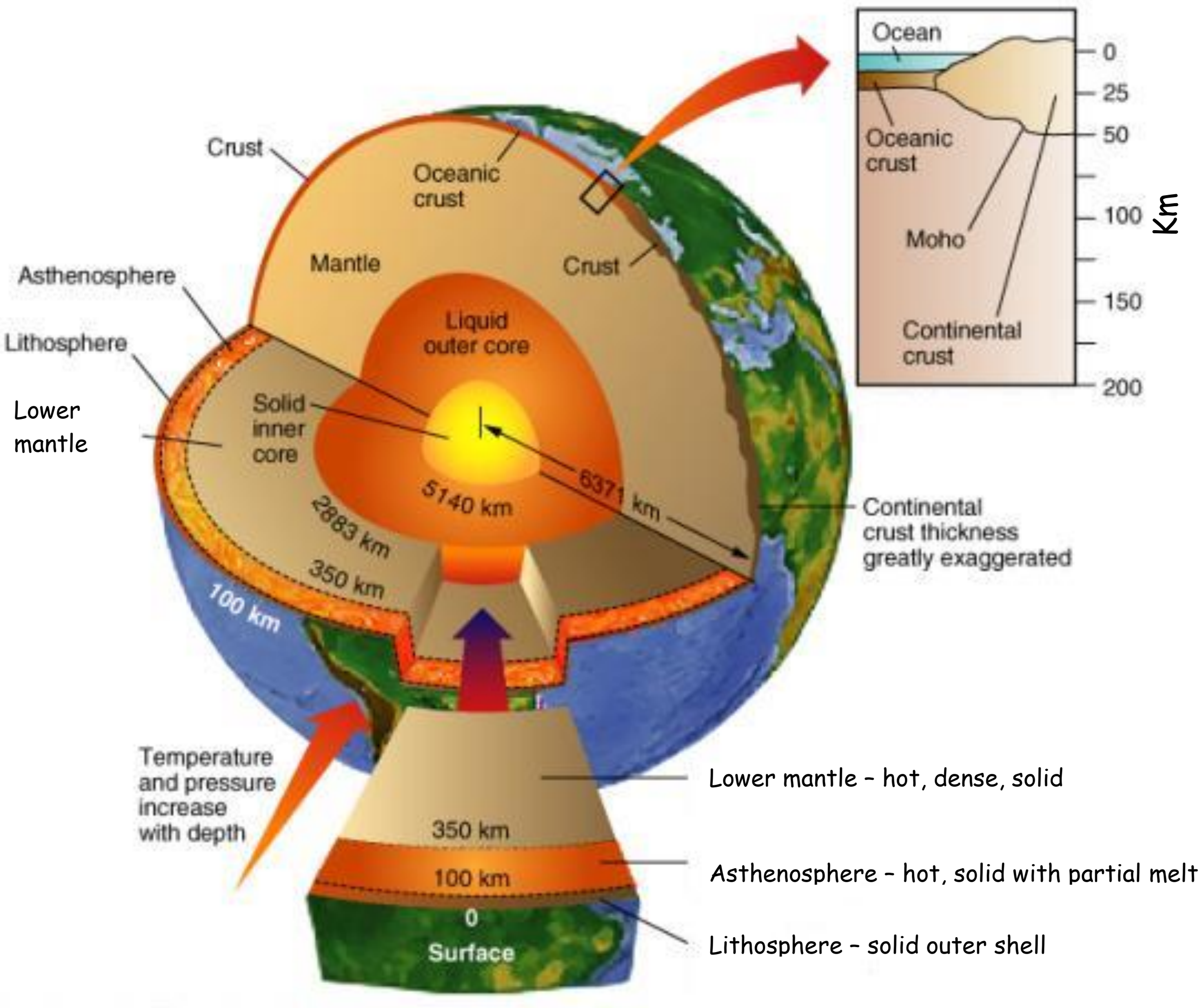
1.3.1 Tectonic processes and hazards

Patterns of Plates and Plate Boundaries

The World map on page 4 shows the distribution of volcanoes and earthquakes around the globe. They are found in similar locations in narrow belts along **plate boundaries**. A map of the World's major plates and plate boundaries (margins can be seen on page 5)

To understand why they occur here we must firstly understand the internal structure of the Earth, which is shown in the annotated diagram below (not shown to scale).

Internal Structure of the Earth



The Layers of the Earth

- The uppermost layer of the Earth is known as the **lithosphere**. This is formed of the crust and top layer of the mantle. These two layers move together, floating on top of the next layer.

- The crust is split into two types: Continental (C) and Oceanic (O).The continental crust is thicker but less dense and so 'floats' a little higher than the oceanic crust which is denser but much thinner.

- In the **asthenosphere** there is tremendous heat and pressure which causes the otherwise solid material to become partially melted. This material can then flow in a series of <u>convection currents</u> much as the wax in a lava lamp does. It is the motion in this layer of the Earth that causes the plates to move.

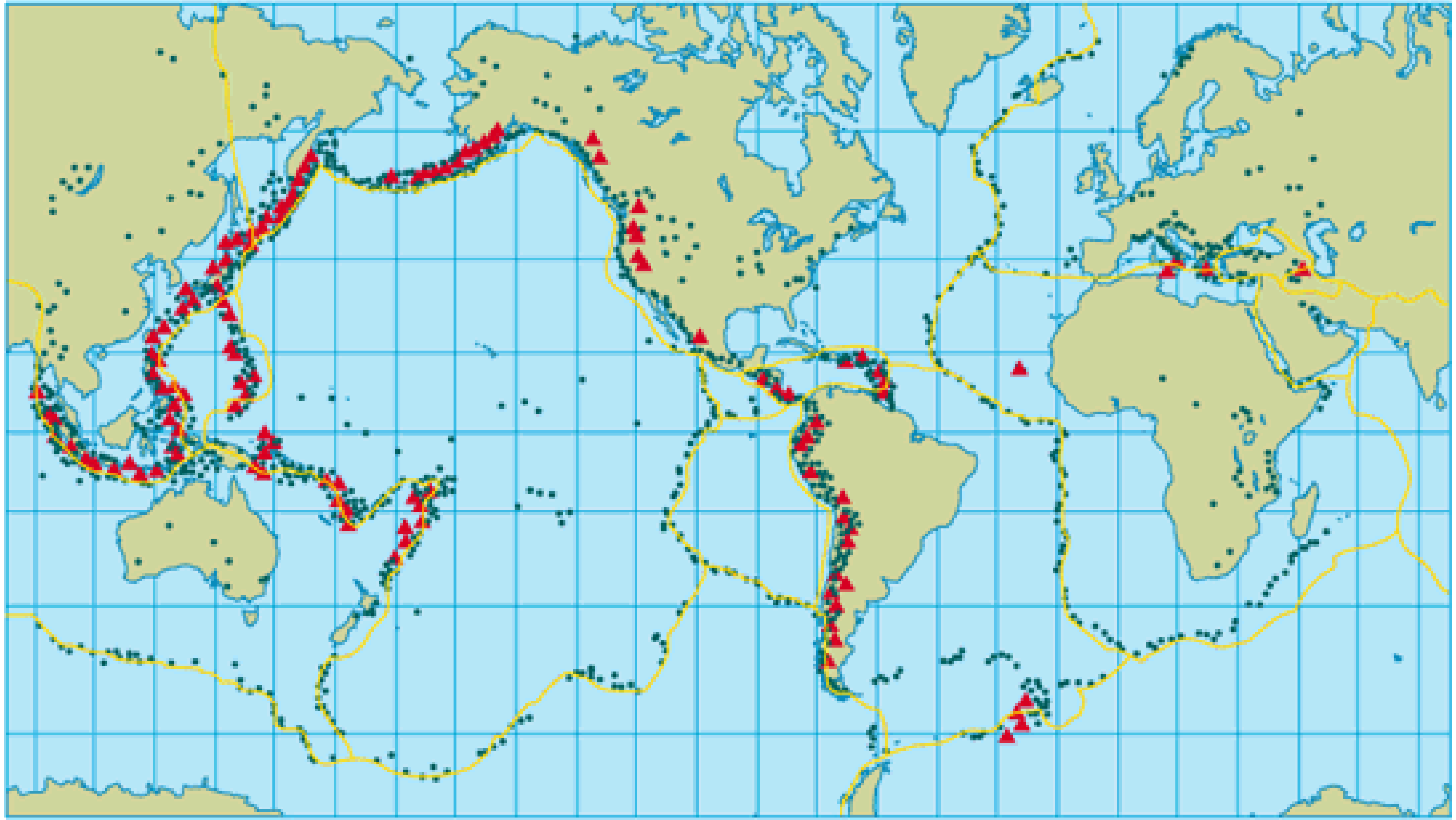
- The rest of the **lower mantle** is hot, dense and mostly solid.

- The **outer core** is a layer of rapidly moving liquid metal (mainly iron and nickel). It is thought that the Earth's magnetic field is generated by strong convection currents in this layer.

- The **inner core** is an extremely hot and dense ball of solid metal at the centre of the Earth. It is so dense that it generates the Earth's gravity field. Decay of radioactive elements in the core generates the heat that drives all of these internal processes.

The study of the movement of the Earth's plates, and the landforms formed as a result of the movement, is called **Plate Tectonics**. Plate tectonics explains why volcanoes and earthquakes are found in narrow belts or **active zones** along the boundaries or margins of the plates.

Distribution of Earthquakes and Volcanoes



■ Major earthquake centres

▲ Active volcanoes

Plate Boundaries and Plate Movement

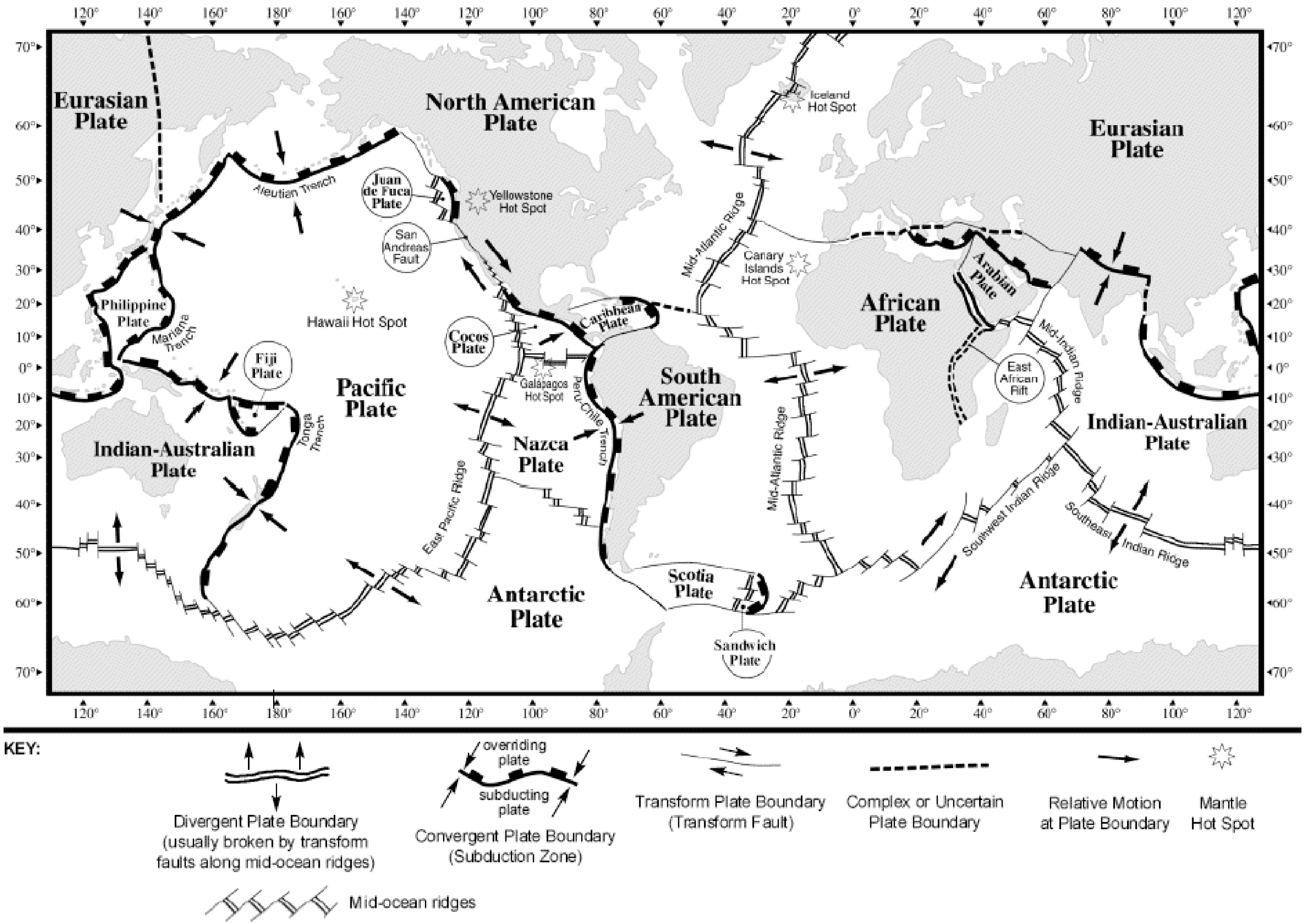


Plate Tectonic Theory

Plate tectonics has its origins in a theory put forward by German scientist Alfred Wegener in 1915. He suggested that all of the continents of the world were once joined together to form one super-continent called Pangaea. Pangaea then became split into two sections – Laurasia and Gondwanaland, and over the last 200 million years, the continents have drifted slowly to their present positions. Wegener called his theory **Continental Drift**.

This theory was later refined into plate tectonic theory in the 1960s as observations were taken of the sea floor.

What evidence supports plate tectonic theory?

1) **Jigsaw fit** of some continents

2) **Rock formations** – The same age, type and formations of rocks have been found to match up in places such as Brazil and Namibia (SW Africa), Norway and USA, India and Australia.

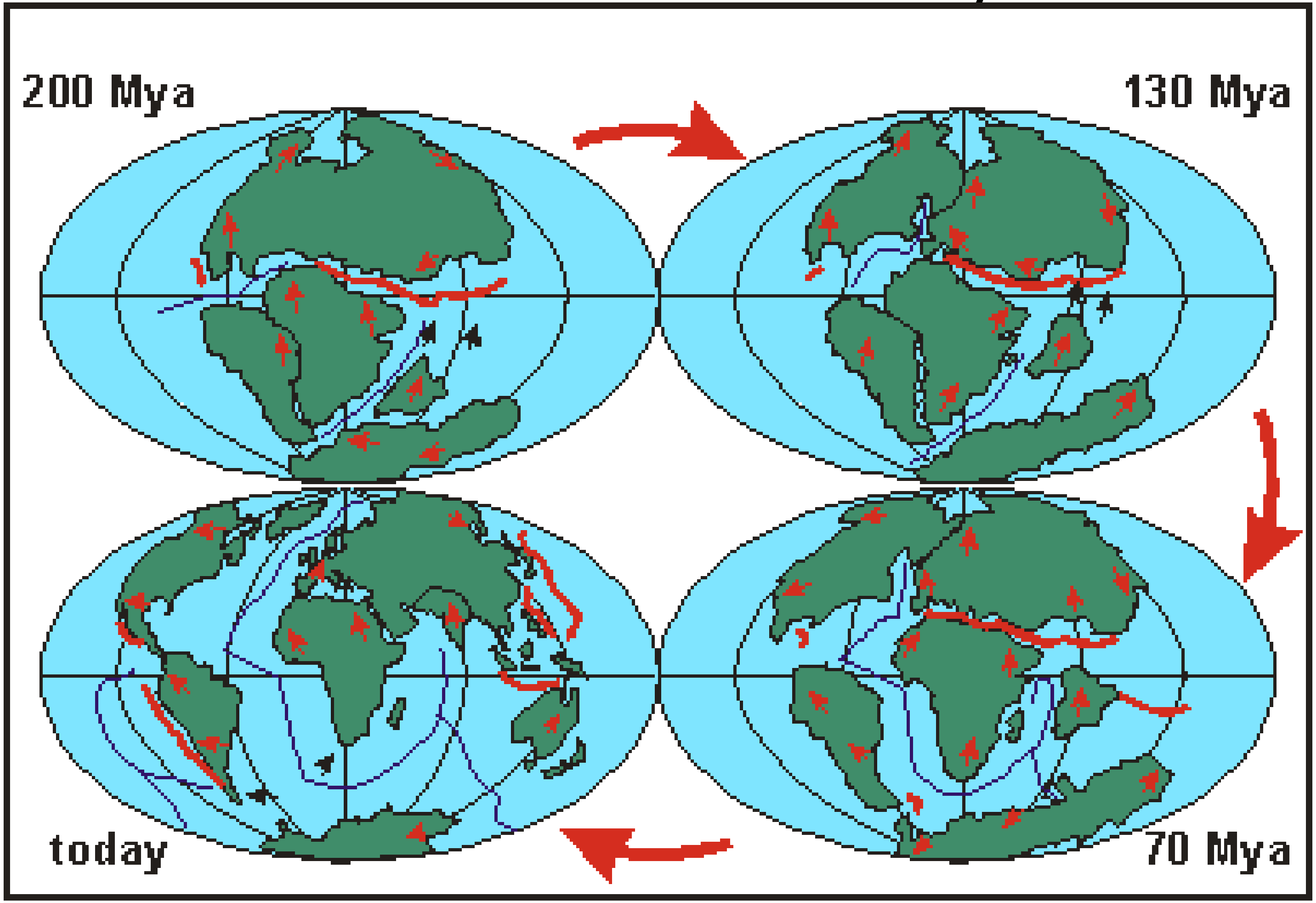
3) **Palaeontological evidence** – Fossils of the Mesosaurus (a small reptile) have only ever been found on the East coast of South America and the South West coast of Africa.

4) **Palaeomagnetic evidence** – When lava cools and crystallises, the magnetic minerals (e.g. iron) that it contains will align with the Earth's magnetic field. This evidence will be stored in the rocks allowing us to work out where the rock was formed.

5) **Palaeoclimatic evidence** – The existence of coral fossils in the rocks in the UK suggest that we once had a much warmer climate indicative of locations nearer to the Equator.

6) **Sea floor spreading** – Oceanography suggests that the ocean crust is much younger than the continental. Studies also show that in some places the ocean plates are moving apart and new crust being formed in between. This process can be measured (on land in Iceland) and changes traced back in time to produce maps of where the continents were in the past.

Plate movement over the last 200 million years

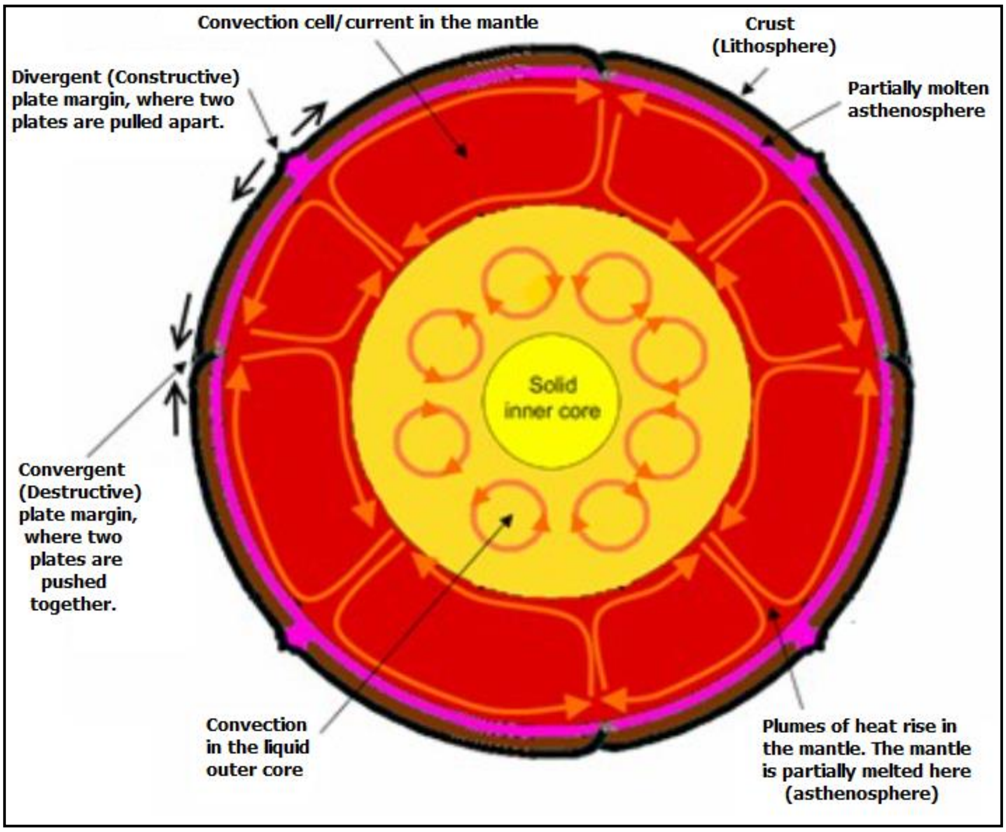


Processes Operating Inside the Earth

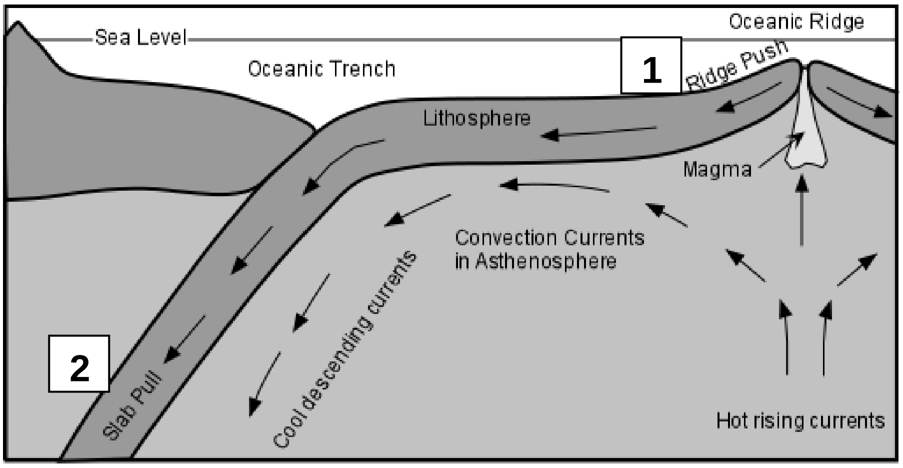
There are a number of processes that govern the plate movements occurring on the surface of the earth, though not all of these are fully understood. This is because most of these processes are happening deep down inside the planet.

Where is all the heat from?

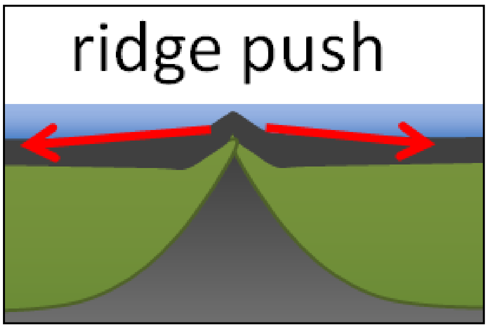
- Tectonic processes are driven by **radioactive decay** in the core.
- This decay generates heat inside the earth, which drives **convection currents** or cells.
- This convection is largely responsible for driving the plate movement in the crust above.



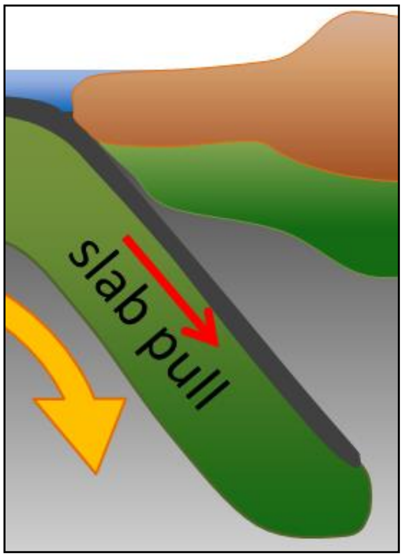
There are two main theories as to how these convection currents actually move the plates. These are illustrated below:



1) **Ridge push** – this is the theory suggesting that the main mechanism driving the plates occurs at divergent (constructive) plate margins. As magma rises it forces the crust to rise at the ridge. As the crust rises gravity then forces it away from the margin, thus driving the crust.



2) **Slab pull** – this however suggest that the main driving force is the subduction of the colder, denser oceanic crust into the mantle. This effectively pulls the oceanic crust along behind it. Many scientists today believe that this is the main driving force behind plate movement, far more so than ridge push.



Types of Plate Boundary/Margin

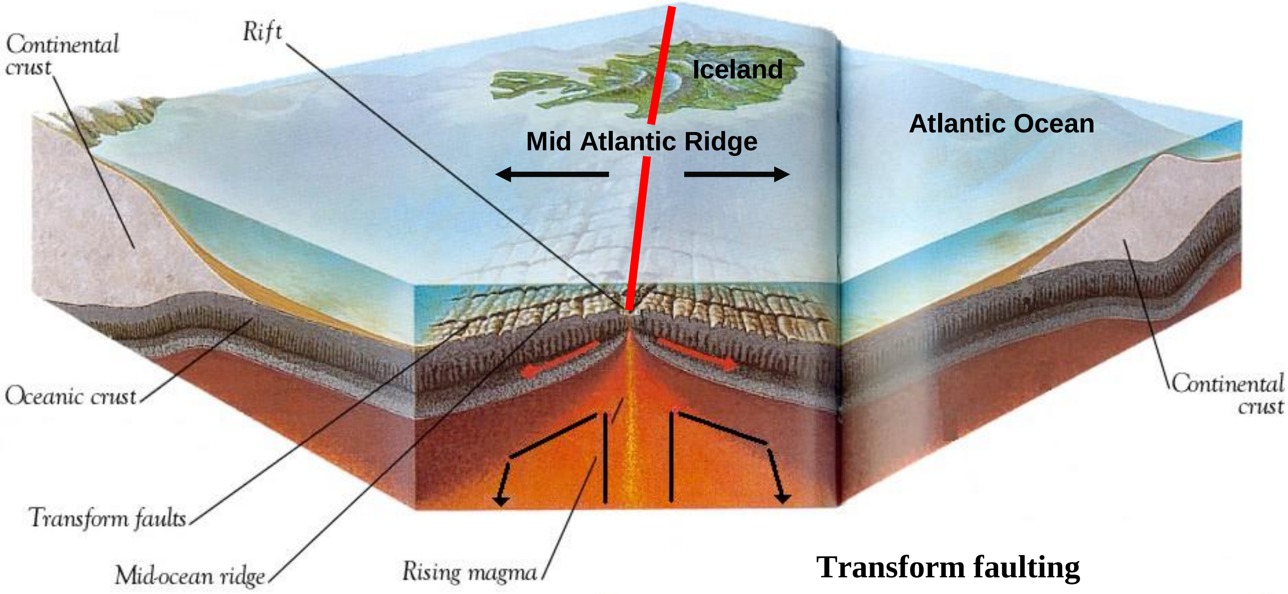
There are three main types of plate boundary:

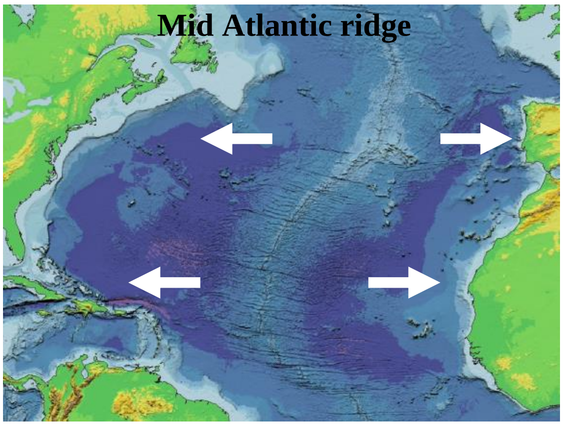
1) **Divergent** (Constructive) – Ocean plate is made as plates move apart
2) **Convergent** (Destructive) – Plates collide (ocean plate can be destroyed)
3) **Conservative** – Plates move along side each other (none destroyed or made)
Also:
4) **Volcanic Hot Spots** – Intra-plate volcanoes

Divergent Plate Boundaries (Constructive, Spreading zones)

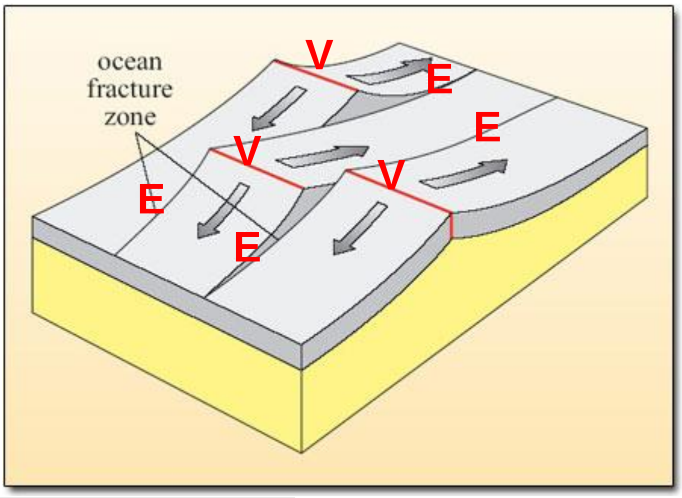
Plate Movement	• Plates move apart, spread
Processes	• Large rift valley occurs as plates move apart • Magma pours into split between plates • Lava solidifies to form new ocean crust • Volcanoes form to produce ocean ridge on either side of central rift • Speed of plate movement differs along boundary so large parallel faults are found
Volcanic Activity	• Lots of volcanic activity near plate boundary • Shield (gentle slopes) or basaltic volcanoes • Eruptions not very violent • Lava is fluid and mobile
Earthquake Activity	• Less activity than other plate boundaries • Small earthquakes are common, larger ones are rare • Few of these events affect people
Examples	• Mid – Atlantic ridge (formed as a result of N&S American plates moving away from Africa and Europe) • Antarctic plate moving away from the Indo Australian plate • African plate splitting along the rift valley

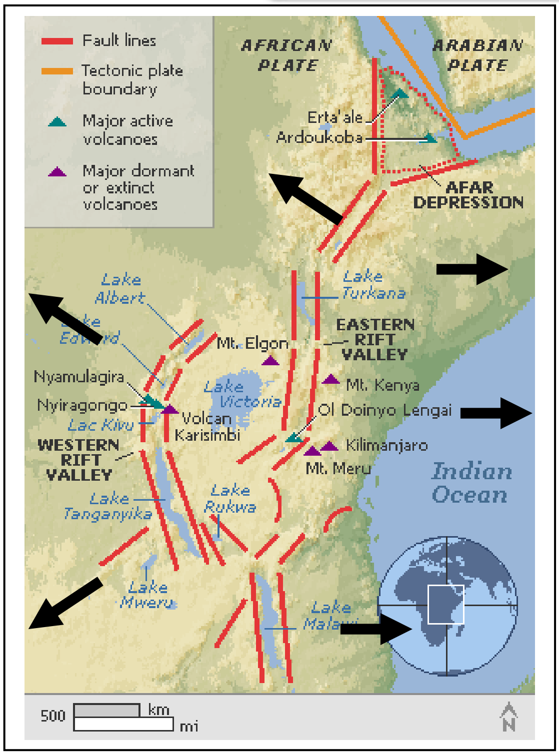
Mid ocean ridges and sea floor spreading





Transform faulting





East African Rift Valley

<u>**Convergent Plate Boundaries** (Destructive)</u>

There are two types of destructive plate margin:

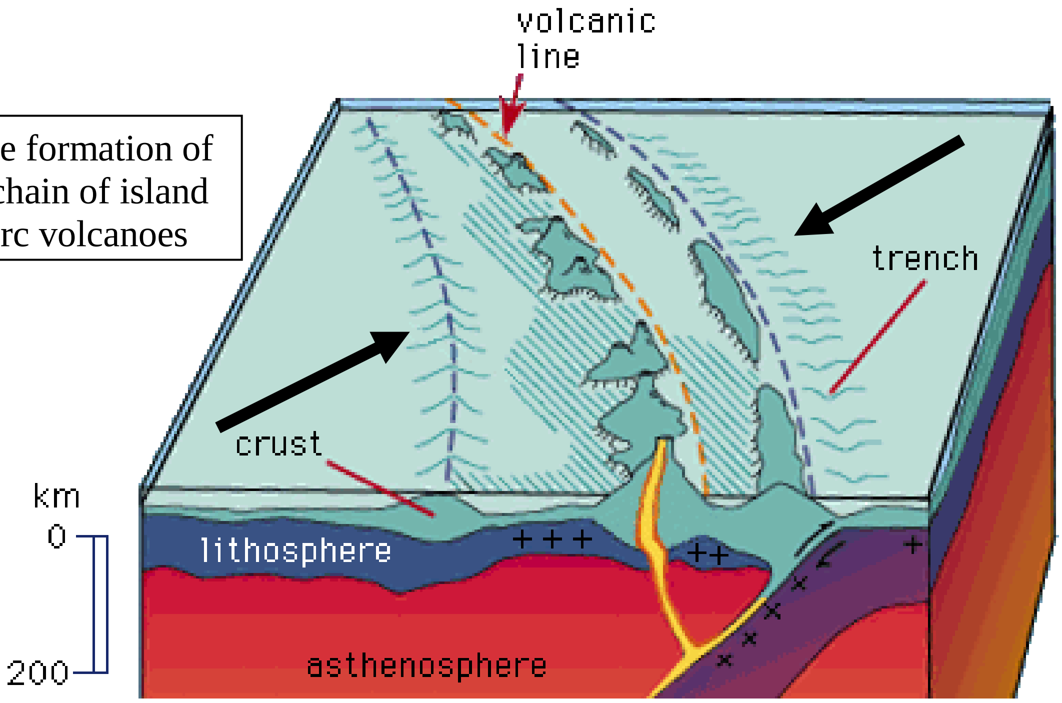
a) Subduction zones (O - O) or (O - C)

b) Collision zones (C - C)

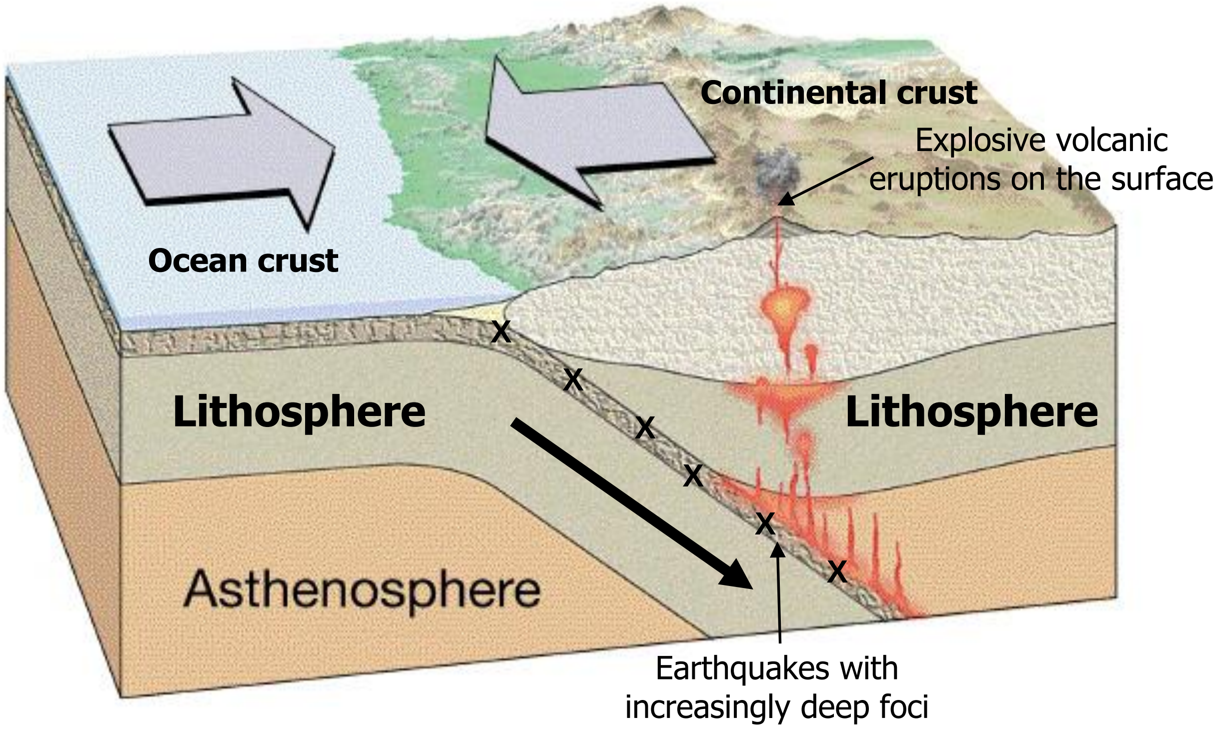
a) Subduction zones	
Plate Movement	• Two plates move together (converge) • Either: two ocean plates or one ocean and one continental
Processes	• The thinner, denser plate is subducted (forced down) below the other • Area of subduction is known as the Benioff zone • The subducted plate melts when pushed back into the asthenosphere creating an area of high magma and gas pressure • Magma is forced to rise through cracks to the surface (magma is thick, viscous and gassy) • An ocean trench with deep water forms at the point of subduction (see diagrams) • Volcanoes form as island arcs (O - O) or in range of fold mountains (O - C)
Volcanic Activity	• Large amounts of volcanic activity • Cone or composite volcanoes (steep sided) • Very violent eruptions
Earthquake Activity	• Large numbers of destructive, violent earthquakes • Shallow focus earthquakes
Examples	• Pacific plate subducted under Philippines plate to form Marianas Trench • Nazca plate subducted under South American plate forming the Andes fold mountains

Ocean plate meeting ocean plate (O – O)

The formation of a chain of island arc volcanoes

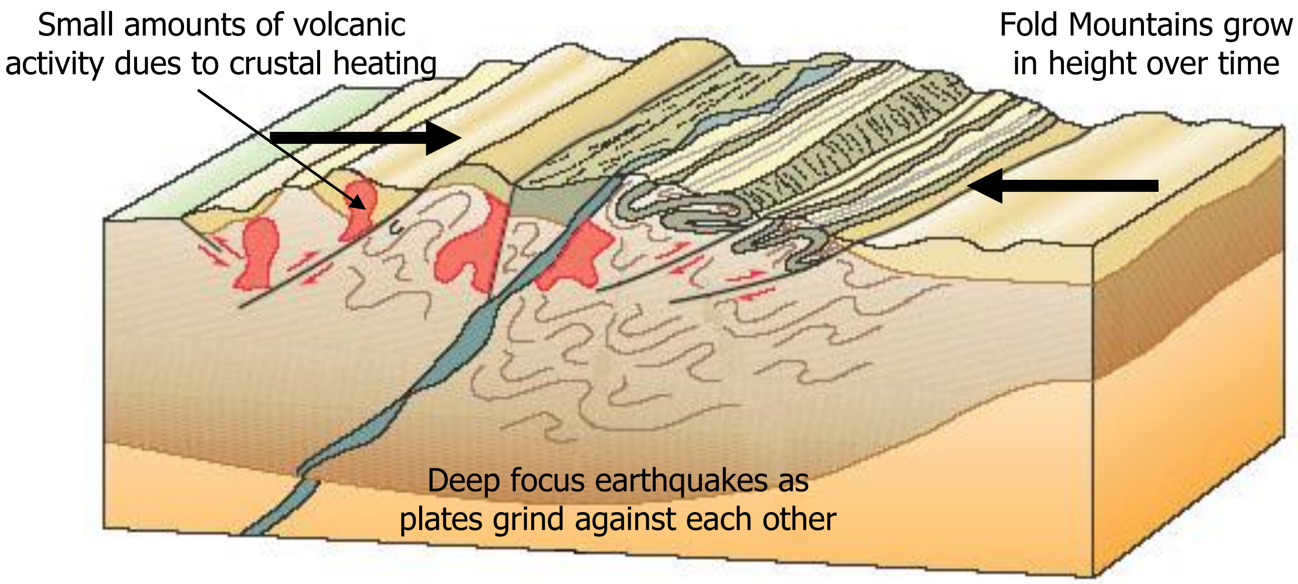


Ocean plate meeting continental plate (O – C)



b) Collision zones	
Plate Movement	• Two continental plates move together and collide
Processes	• Plates are too thick and not dense enough to subduct, so the sediments between the plates get compressed and crumple • They buckle and fold upwards to form huge chains of fold mountains
Volcanic Activity	• Very little volcanic activity as the plates get thicker and thicker as sediments fold upwards
Earthquake Activity	• The constant movement of the plates towards each other creates pressure • Huge faults develop along the collision zone • Earthquakes are quite common and can be very destructive as the focus is near the surface
Examples	• Collision of the Indian and Eurasian plates to form the Himalayan fold mountains • Mount Everest is still growing, but only at about 2cm per year • The African and Eurasian plates moving together and forming the Alps

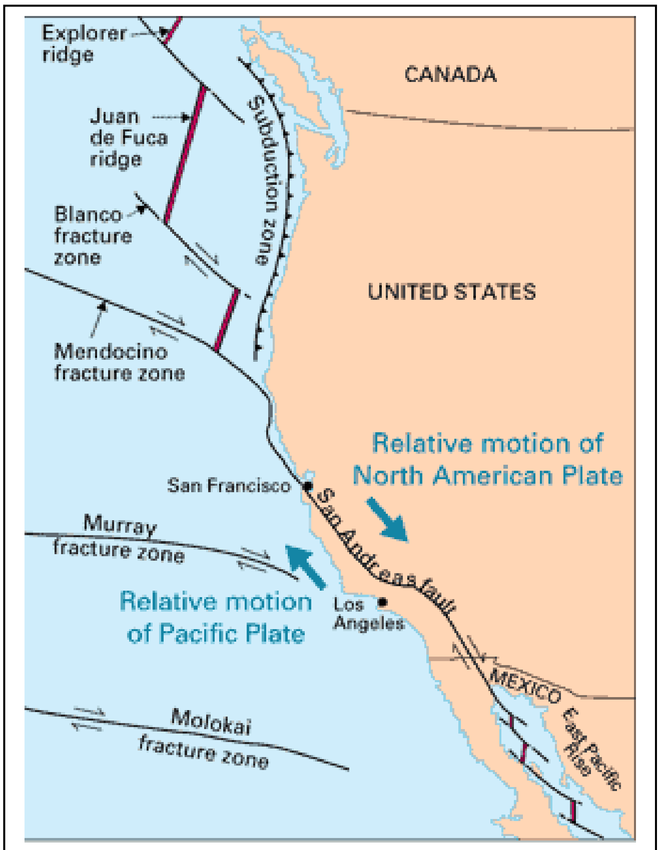
Collision zones and Fold Mountains

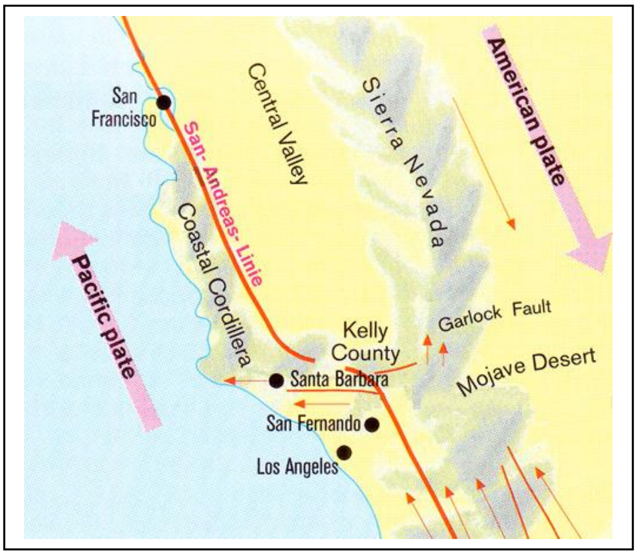


Conservative Plate Boundaries (Sliding zones)

Plate Movement	• Two plates slide past each other – either in the same or opposite directions
Processes	• Huge transform faults develop • Also patterns of parallel faults can be seen
Volcanic Activity	• Very little
Earthquake Activity	• Intense earthquake activity as plates rub and grind past each other causing friction • Many shallow focus earthquakes
Examples	• Boundary between the North American plate and the Pacific plate along the San Andreas fault • Between the Antarctic and African plates in the South Atlantic/Indian oceans

The San Andreas Fault

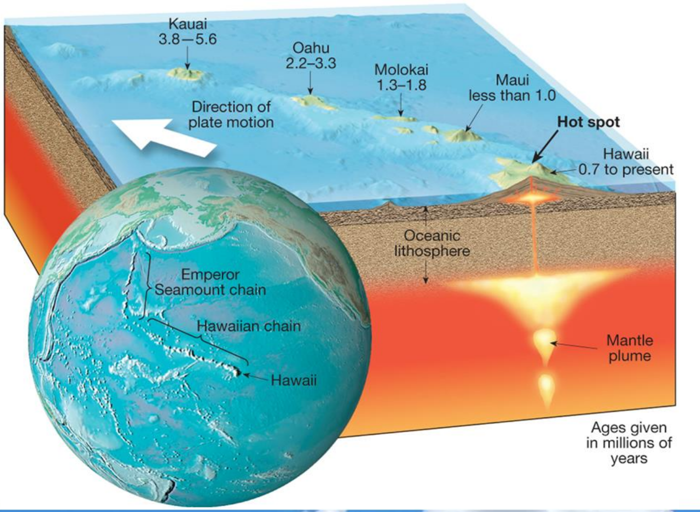




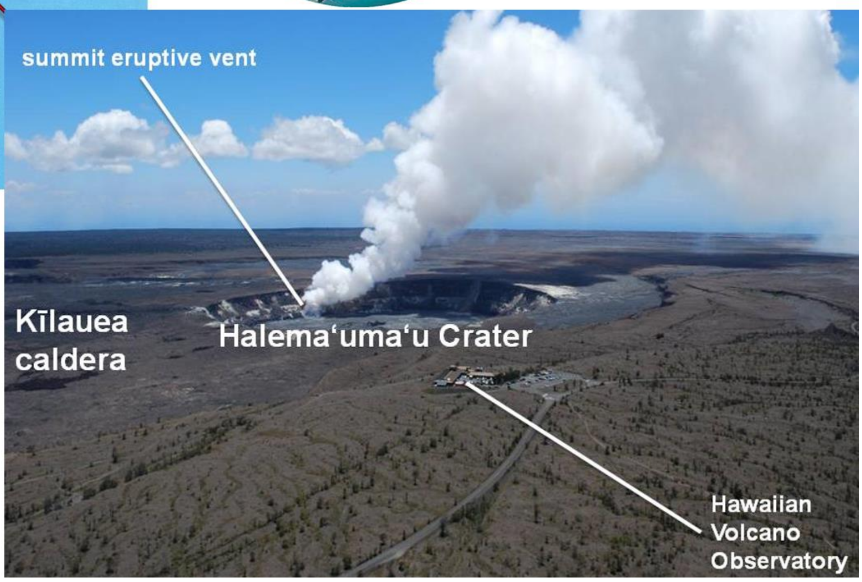
The movement of the plates is relative to one another. They are both actually moving to the NW. However the Pacific plate moves faster, so the North American plate appears to go to the SE.

Volcanic Hot Spots (Intra-plate volcanoes)

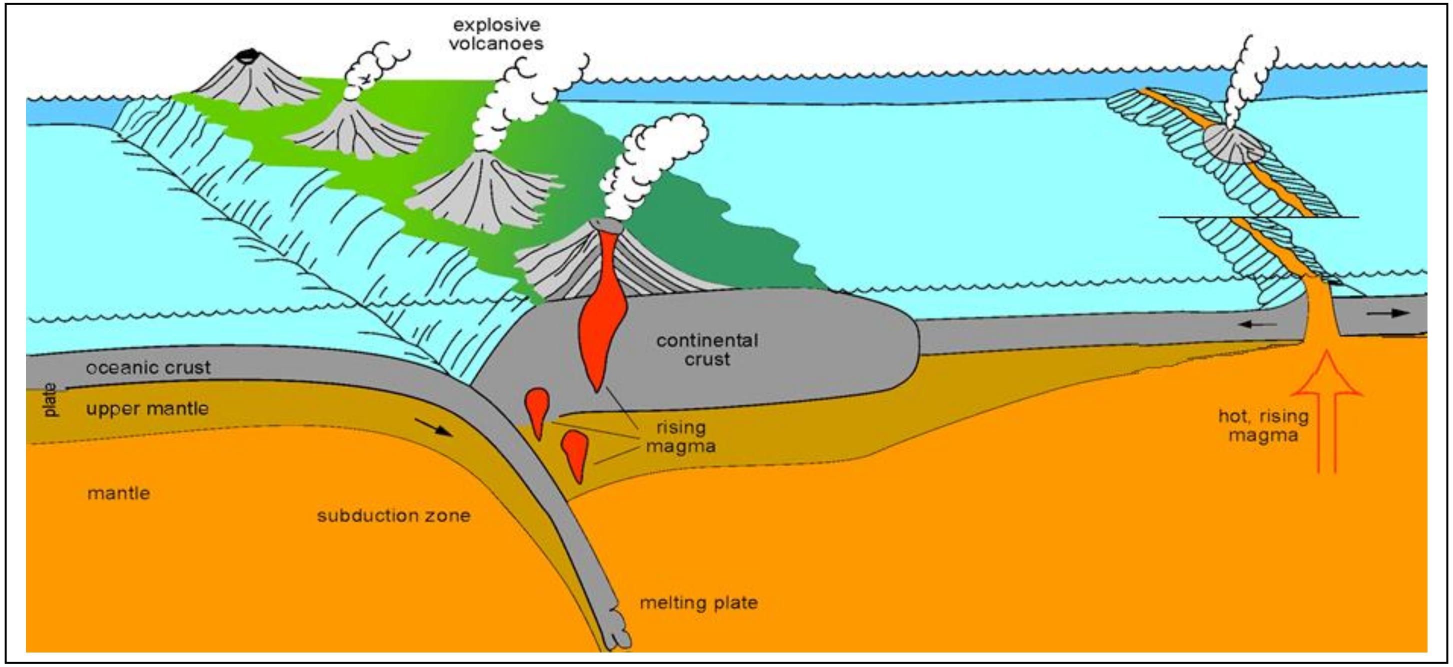
Plate Movement	• Across a stable mantle plume or hot spot
Processes	• Large scale upwelling of magma from deep inside the mantle • Volcanic seamounts grow into volcanic islands
Volcanic Activity	• Regular eruptions of basaltic (runny) lava • Quite predictable and relatively safe
Earthquake Activity	• Minor earthquakes associated with the volcanic activity
Examples	• Hawaiian islands in the centre of the Pacific plate • Yellowstone on the North American plate • St. Helena in the Atlantic Ocean

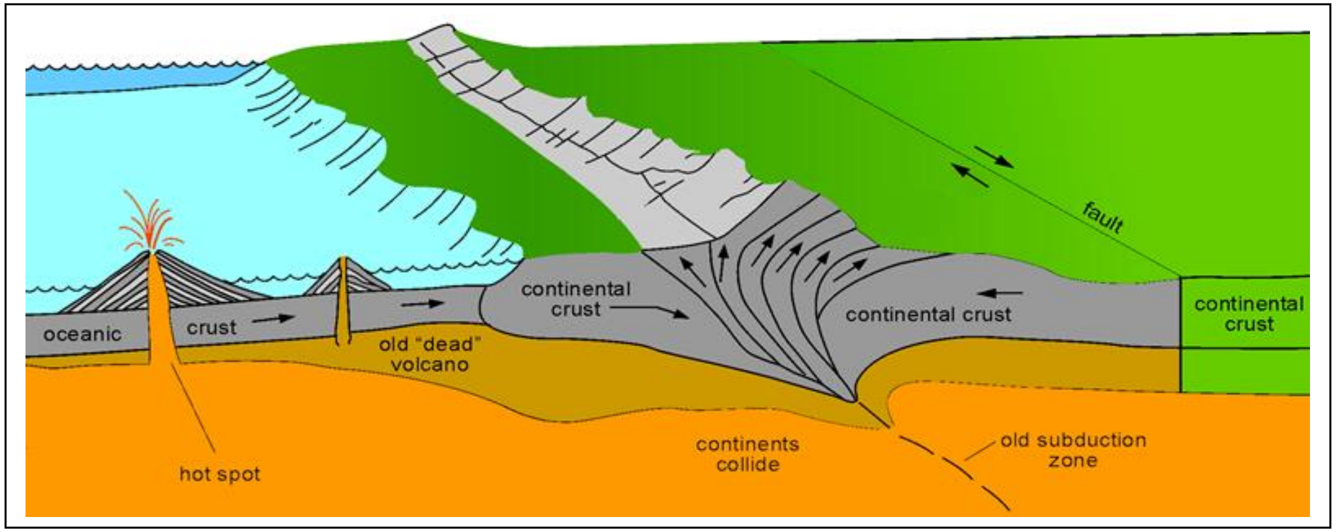


The Hawaiian hot spot is a stable plume of magma (currently under Hawaii). As the Pacific plate moves over the hot spot new seamounts will form and grow into new volcanic islands.



Summary of Plate Boundaries





Hazards and their characteristics

All physical hazards including tectonic ones vary but each has a particular set of characteristics.

For example an earthquake will typically last for 10-20 seconds but can still cause considerable damage. However a drought may last for months or years, but if plans were in place may cause minimal damage.

You are now going to do some research in order to answer the following question (use the prompts in the table below to help you):

What are the different factors that will affect the severity of the impact of tectonic hazards?

Here are a few ideas to get you started with your research:

Factors	Notes/Ideas
Magnitude	• How strong was the event measured on the: * Richter Scale * Mercalli Scale * Volcanic Explosivity Index (VEI)
Frequency	• How often do they or are they likely to occur? • Is there a regular pattern? • Is the area prone to these hazards?
Duration	• How long is the hazard likely to last? • How long are the effects likely to last?
Speed of onset	• How quickly does the hazard occur? • Are the impacts immediate? • Is there preparation time?
Predictability	• Are there methods of predicting the event? • Are these methods reliable? • Can warnings be given?
Areal extent	• How wide ranging are the effects likely to be? • Is it a localised event? • Are the effects likely to be global?

1.3.2 Volcanoes, processes, hazards and their impacts

Volcanoes as a Hazard

"The mountain was blown to pieces. The side of the volcano was ripped out and then hurled straight towards us as a solid wall of flame. The wave of fire was on us like a lightning flash. It was a hurricane of fire."

(Mount Pelee, Martinique, Caribbean, 1902)

"It was like the end of the world. Heavy thick clouds boiled up, white and blue lightning flashes crackled through the mountains"

"Mud rained from the sky in clumps the size of golf balls. Ash drifted in and five people were taken to hospital unable to breathe properly"

"It was unbelievable. It gradually went from bright sunlight to grey, to muddy brown to black. By noon it was as dark as the darkest night you have ever seen."

(Mount St. Helens, USA, 1980)

Most volcanoes occur along plate boundaries (see page 17). Many volcanic eruptions occur in unpopulated locations (e.g. submarine eruptions at mid ocean ridges) and so are not a hazard to people.

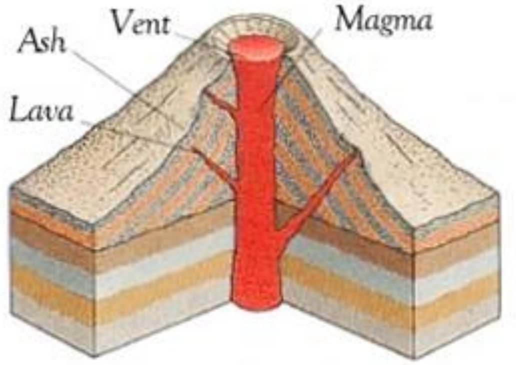
Although many volcanic eruptions are spectacular and attract much media attention, the hazard impact caused by a volcano is not as great as that of an earthquake.

There around 1,500 active volcanoes in the world. However on 500 of these have erupted in historical time. Nearly 75% of these active volcanoes are located around the Pacific 'Ring of Fire'.

Types of Volcano

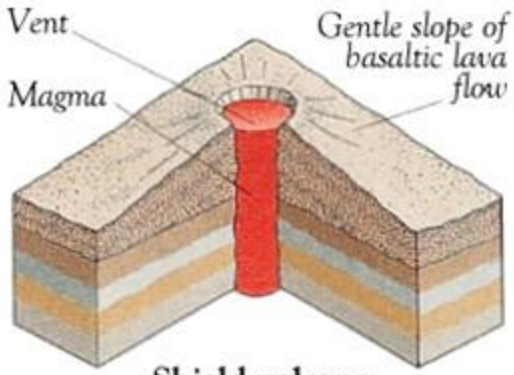
Volcanoes vary considerably in the type of eruption, shape and potential hazards. The type of volcano is related to the type of plate margin and type of magma.

a) **Composite** (Cone or Andesitic) volcanoes – These tend to very **explosive** and erupt with great force. They extrude lava which is thick, viscous and gassy. The cones that build up are therefore steep sided and made up of alternating layers of ash and lava. As a result they are known as composite cones. These volcanoes occur along **convergent** or destructive boundaries and are very hazardous. Examples include Mount St. Helens in the USA and Mount Pinatubo in the Philippines.



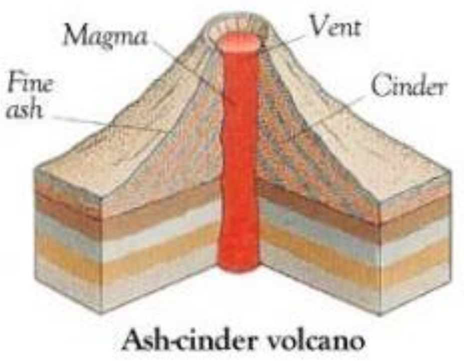
Composite volcano

b) **Shield** (Basaltic) volcanoes – The eruptions from this type of volcano are not as violent or explosive. The lava is fluid and mobile and pours out easily and so the eruptions are often termed **effusive**. They tend to form gentle sided, wide based volcanoes which are lower in height, hence the name shield. They usually occur at mid ocean ridges or near to rift valleys at **divergent** or constructive plate boundaries. Examples include Mount Etna in Italy and Kilauea on Hawaii.



Shield volcano

c) **Cinder cone** volcanoes – These develop where there is a large amount of pyroclastic material thrown into the air. They are often steep sided and made of loose material such as ash, clinker and volcanic bombs. They are usually associated with volcanoes at **divergent** or constructive plate boundaries, sometimes growing on the sides of larger shield volcanoes. They are usually formed during an explosive event or lava fountain. Examples include Paricutin in Mexico and Eldfell in Iceland.



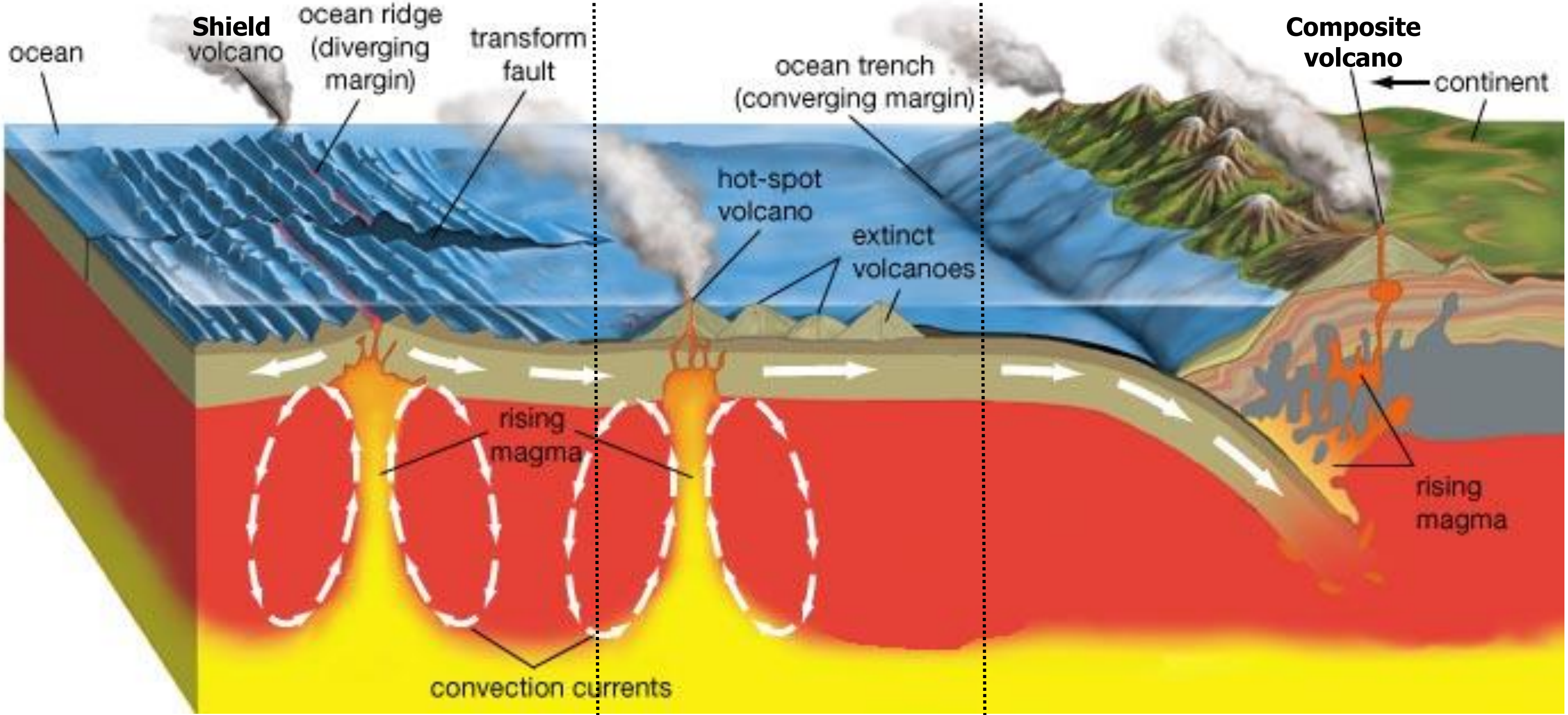

Mount Mayon a classic composite cone volcano in the Philippines


Eldfell a cinder and ash cone in Iceland


The summit of the gentle sided shield volcano at Kilauea, Hawaii


Paricutin a cinder cone in Mexico

Volcanic Activity and Plate Boundaries



* Divergent (constructive) boundaries with fluid lava
* Effusive rather than explosive
* Low, shield volcanoes and cinder cones

* Large cracks or fissures
* Huge amounts of lava
* Constant eruptions
* Gentle sided volcanoes

* Convergent (destructive) boundaries with viscous lava, very explosive
* Steep sided composite volcanoes (ash and lava)

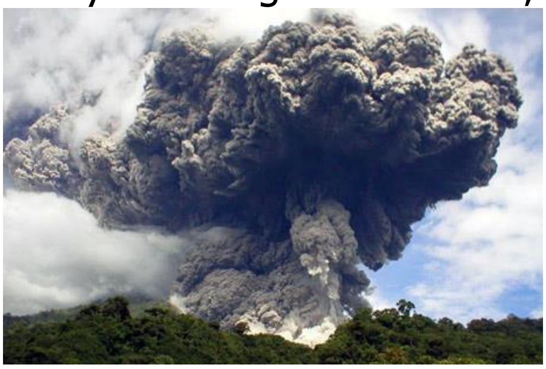
Volcanic Hazards

Primary Hazards

These are associated with the products ejected by the volcanic eruption:

- Pyroclastic Flows (or Nuee Ardentes meaning glowing clouds) – These result from the frothing of molten magma in the chamber and vent of a volcano. The gas bubbles, expands and bursts violently and explosively to fragment the magma/lava. As a result a turbulent mixture of hot lava, gases, ash and pumice is formed into a red hot dense cloud. This cloud will collapse once released and flow down the sides of the volcano at speeds of up to 450 miles per hour (700km/h). The material ejected can be up to 1000^{o}C. Pyroclastic flows are the most threatening volcanic hazard to humans and are responsible for over 70% of all deaths during volcanic eruptions. Due to the high temperatures involved, plastic, glass and even metal will melt. People are killed by burns and also by asphyxiation by inhaling the hot gases.

- Ashfall or Ash clouds – All of the material ejected from the volcano during the eruption eventually falls to ground as ash, pumice, clinker or volcanic bombs. The initial eruption can blast ash clouds up to 20km into the atmosphere. Theses ash clouds can circulate the globe over the subsequent days and weeks. This can be deposited on buildings, transport routes or farmland. Large amounts of ash can be very heavy and can cause buildings to collapse. Ashfall can also clog rivers and cause massive flooding.



❖ Lava Flows – Some are very fast, very hot and so can cause a threat to life and destroy farmland and buildings. However with distance lava slows down and cools becoming less of a threat.

❖ Volcanic Gases – These can be very dangerous as many gases are toxic. Sulphur dioxide and carbon dioxide can both cause death within 10 minutes if inhaled. CO_2 is particularly deadly as it is odourless and invisible to the naked eye. As a result volcanic gases can be a silent killer. This happened at Lake Nyos in Cameroon in 1986.

Secondary Hazards

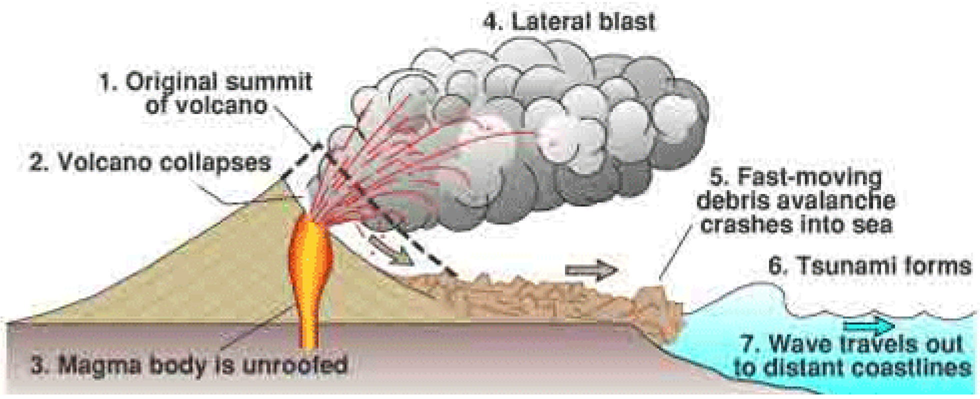
These are hazards that occur as a *later result* of the initial eruption:

❖ Landslides and Ground Deformation - Volcanoes bulge prior to an eruption as pressure builds and magma rises inside. This can cause small landslides and rock falls off the slopes of the volcano. Also the sudden uncorking of a magma chamber can cause a vast landslide on the side of the volcano as happened at Mt. St Helens in 1980.

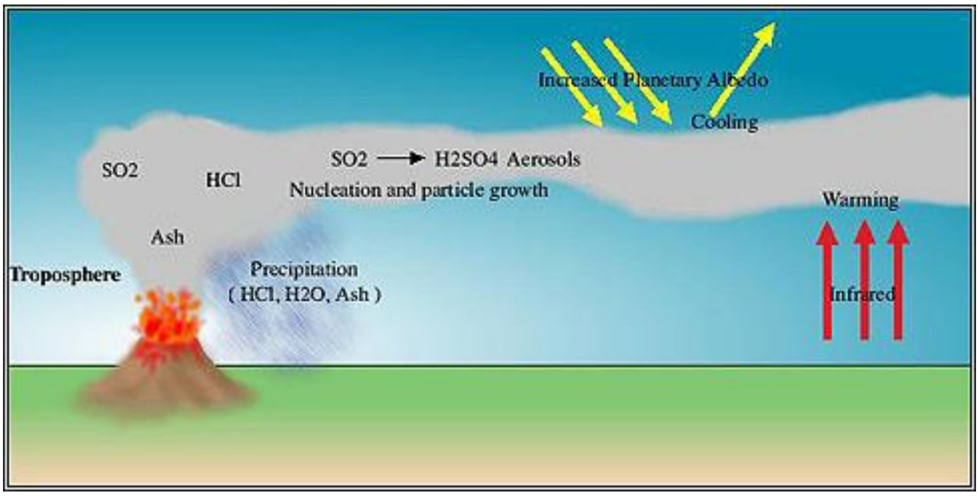
❖ <u>Mudflows</u> (Lahars) – These occur alongside flooding after large ash falls. Rain falls onto soft ash causing huge piles of sticky, concrete like mud to flow down river channels. Also in mountainous areas heat form a volcanic eruption can melt ice and snow causing large scale flooding onto the surrounding land. This happened at Nevado Del Ruiz in Colombia in 1985.

❖ <u>Jökulhlaups</u> – This is the Icelandic name for volcanic eruptions that occur underneath ice sheets. They cause vast glacial outburst or floods that can spread for hundreds of miles. The 2011 eruption of Eyjafjallajökull in Iceland creating a vast flood along the south coast.

❖ <u>Tsunamis</u> – These are very rare. However, one of the most devastating tsunamis in recent centuries occurred after the eruption of Krakatau, Indonesia in 1883. Over 36,000 people died as the volcano exploded and collapsed creating a 30 metre high wave that flooded surrounding islands.



- <u>Global Temperature Change</u> – The volcanic dust and ash from a major eruption reflect incoming solar radiation and so reduces the heat reaching the Earth. This can lower temperatures on a global scale. 1816 has become known as 'the year without a summer'. Following the huge eruption of Tambora in Indonesia in 1815. Ash and dust caused large temperature changes in the northern hemisphere. Temperatures dropped by nearly 3°C and crops failed across the USA, Canada and Europe. It is thought that up to 2 million people may have died as a result. However large volcanic eruptions can also add to global warming as large volumes of CO_2 and SO_2 are released.



The Impact of Volcanic Eruptions

We are going to look at a number of case studies in order to discover the impact of the events on the local area and the region as a whole.

For each event you will need to look at the:

- **Demographic** effects – how is the population affected?
- **Social** effects – how are people's lives affected?
- **Economic** effects – how are jobs and money affected?

The main events that we will study are:

Mount Pinatubo, Philippines 1991
Nevado del Ruiz, Colombia 1985
Mount Etna, Italy 1992, 2002, 2007

For each event you will need to gather the following information:

Location	Date	Type of volcano/eruption
Cause	Time	Tectonic setting
Recovery	Cost	Primary and secondary hazards
Responses	Casualties	Short and long term effects

* Finally try to assess the effects on a variety of scales:

- Local (the immediately affected area)
- Regional (the wider are in that country)
- Global (across the world)

1.3.3 Earthquakes, processes, hazards and their impacts

Earthquakes as a Hazard

"I felt I was trying to stand on a bed of jelly when the main earthquake hit"

"During the earthquake it was like walking on a water bed or rubber mattress"

"We saw the earth all around heaving in a most frightful manner. The earth resembled waves coming from opposite directions and meeting in a great heap and then falling back. Every time the waves seemed to fall back, the ground opened slightly."

Over 3,000 earthquakes occur every year, but fewer than one hundred cause damage to property and loss of life. On average about 30,000 people die every year from earthquakes.

Earthquakes cause far more damage and are far more hazardous than volcanoes, as they occur suddenly with little or no warning. Although they usually don't last very long (typically a few seconds) they can cause great damage.

Very often, large numbers of people live on or near earthquake zones e.g. Japan, California, China, Mexico City and Indonesia.

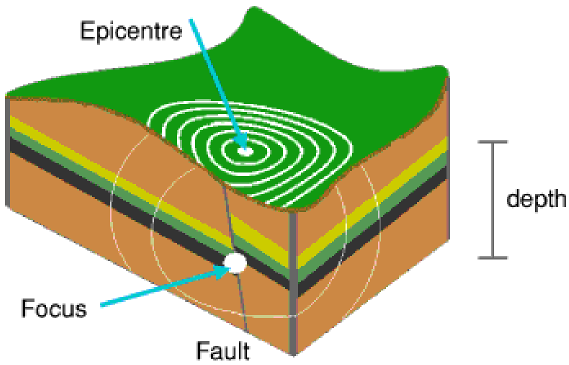
Damage in the town of Amatrice following the August 2016 Central Italy Earthquake

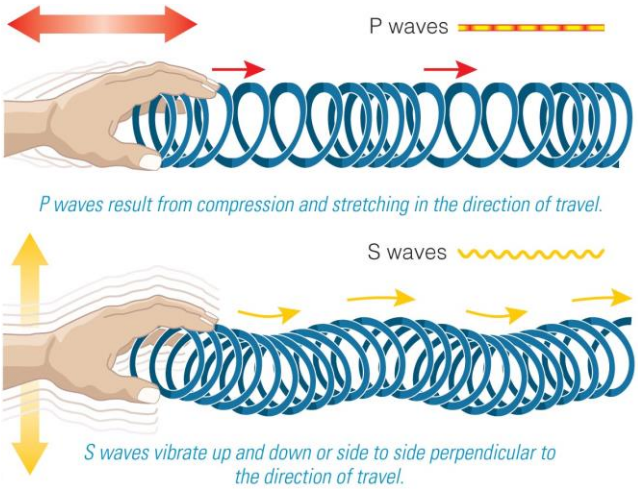
Rescue teams search the rubble of Kathmandu following the April 2015 Nepal Earthquake

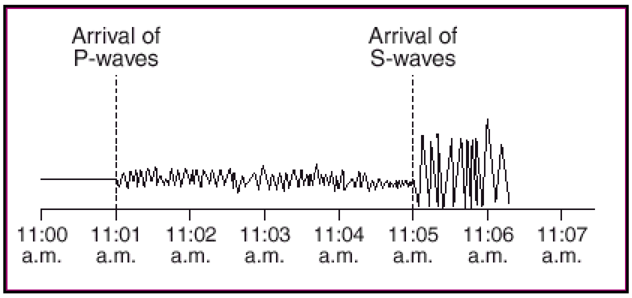
The Cause of Earthquakes

Earthquakes occur when two tectonic plates move suddenly against each other. The rocks usually break apart underground at the **focus** and the earth shakes as waves of energy are transmitted outwards. Waves spread in all directions and the point on the surface where they reach first is known as the **epicentre** (usually directly above the focus). If an earthquake occurs under the sea it can displace the water causing a tsunami.

Pressure builds at plate boundaries due to the heat and friction generated by large masses of rock. There are two main types of energy waves (seismic waves) produced during an earthquake, P and S waves. **P waves** are the fastest and first to arrive at the epicentre. **S waves** are slower but usually more powerful. These waves are measured using a **seismometer**.







Earthquakes can be measured on two scales:

- Richter scale – this measures the magnitude or strength of the seismic waves. It is the most commonly used and understood.
- Mercalli scale – this measures the intensity of shaking and so the effects. Its measurement is affected by ground conditions.

Shallow focus earthquakes are more damaging than deep focus earthquakes as the point of fracture is closer to the surface. This means the waves have less time and distance to dissipate.

The severity of an earthquake and its human impact depends on a number of physical and human factors:

PHYSICAL FACTORS	➢ Location of the epicentre ➢ Depth of the focus ➢ Foundation rock/soil type ➢ Duration of the event ➢ Time of day
HUMAN FACTORS	➢ Building style ➢ Land use and extent of settlement ➢ People's response/reactions ➢ Community preparedness ➢ Availability of emergency services ➢ Ability to recover ➢ Wealth of the area

Earthquake Hazards

Primary Hazards

Violent shaking of the ground causing:-

- Collapse of buildings killing or injuring people inside them
- Homelessness – people often placed in temporary shelter or refugee camps
- Damage to infrastructure – roads, railways, communications
- Collapse of bridges, raised motorways etc.
- Services disrupted – water, sewage, gas, electricity
- Huge cracks opening up in the ground
- Gas and oil pipes or pipelines fracture which may cause fires

Secondary Hazards

When the earthquake occurs it could then cause:-

- Landslides or avalanches
- Tsunamis
- Liquefaction – sediments rich in water lose their cohesion as they violently shake. Buildings sink into the ground.
- Lack of food – crops destroyed or supply disrupted
- Economic disruption – poor transport so businesses suffer
- Spread of disease – due to lack of medical care and conditions

The Impact of Earthquakes

We are going to look at a number of case studies in order to discover the impact of the events on the local area and the region as a whole.

For each event you will need to look at the:

- **Demographic** effects – how is the population affected?
- **Social** effects – how are people's lives affected?
- **Economic** effects – how are jobs and money affected?

The main events that we will study are:

Kobe, Japan 1995
Sichuan, China 2008
Haiti, 2010
Tohoku, Japan 2011
Nepal 2015

For each event you will need to gather the following information:

Location	Date	Strength and length of the event
Casualties	Time	Primary and secondary hazards
Recovery	Cost	Both short and long term effects
Responses	Cause	Tectonic setting

* Finally try to assess the effects on a variety of scales:

- Local (the immediately affected area)
- Regional (the wider are in that country)
- Global (across the world)

1.3.4 Human factors affecting risk and vulnerability

As seen previously (page 31), there are a number of human factors that can affect the risk and vulnerability of a region or country to tectonic hazards.

Economic Factors (those related to wealth, employment and poverty)

In MEDCs

People are far more likely to take a more **POSITIVE RESPONSE,** by looking for practical ways of coping and living with the hazard. This is referred to as **HAZARD MANAGEMENT** .This involves adjustment and modification. People accept that the the natural event *will* happen and so they need to take **ACTIVE** steps to prepare themselves for this future event and to minimize the threat of damage to people and property. This involves what is referred to as the 3 P's policy.

This positive action is very much dependent on –

a) **a higher level of education** which affects how they perceive the hazard, and accept that the hazard does exist.

b) **a higher level of capital and technology** to be able to take action and respond to the hazard.

c) **a better knowledge and understanding** of the hazard due to more records and monitoring.

In LEDCS

People are far more likely to take a **NEGATIVE RESPONSE** and ignore the hazard (i.e. pretend it does not exist**). Lower levels of education** and **economic development** mean that LEDCs **do not have the know-how, capital or technology** to take an active response to the hazard. As a result, it has been estimated that 95% of the total loss of life caused by all natural hazards have occurred in the LEDCs.

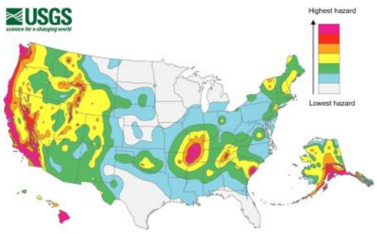
Social Factors (related to people's way of life and living conditions)

In LEDCs people often live in poor quality housing. Sometimes this is made by the people themselves in shanty towns. There are often large numbers of people crowded into these buildings living in poor conditions with no running water, medicine or sanitation. As a result of this difficult way of life, tectonic hazards are likely to affect these areas and people far more than people living in comfortable conditions in MEDCs.

Political Factors (related to how a country is organised or run)

The organisation and governance of a country has a huge bearing on its ability to cope with tectonic hazards. Contrast the two examples below:

<u>USA</u> – It is estimated that the USA spends (directly and indirectly) over $9.5 billion on earthquake monitoring, education, aid, relief and research each year. In 2015 there were 134 earthquakes over 6 on the Richter scale recorded in the USA. However in the last 100 years there have been just over 750 deaths due to earthquakes. This is in part due to FEMA (Federal emergencies management agency) which is a government run organisation in charge of planning for, managing and monitoring hazards across the country.



<u>Haiti</u> – Haiti was witness to one of the worst earthquakes in recorded history when over 300,000 people were killed in 2010. Haiti has had a chaotic political history and as a result has not had strong government or leadership. Haiti is also very poor and has little money to spend on earthquake protection, monitoring or relief. There is little local, regional or national co-ordination of emergency services and schools and hospitals are poorly prepared.

Other Geographical Factors

There are many other things that can affect the risk and vulnerability of an area to hazards:

1) Location – urban areas are far more prone to damage from earthquakes, simply due to the fact that they conatin more builidngs likely to cause death. However rural areas can become cut off, ledaing to people suffering more long term. These isolated areas are often the most vulnerable of all.

2) Time of day/day of week/time of year – most areas are more vulnerble during the rush hours and times when people are moving. Night time tends to be quite safe as people are at home were they are most comfortable and likely to act more calmly. Winter is the worst time of year as people can often be left with no shelter and food/water are harder to come by.

3) Population density – It goes without saying that densely populated areas are the ones at greatest risk. Some builidngs may house thousands of people either at work or living there. Sparsely poluated rural areas are unlikely to be as severly affected.

1.3.5 Responses to tectonic hazards

How many of the P's do you know?

Most Geographers refer to the three P's of hazard management and control. These are generally listed as:

Prediction – attempting to find out where and when a hazard will occur.

Protection – building structures that will help people to survive hazards.

Preparation – educating people ready so that they know how to act.

Active responses to hazards

Page 33 refers to the active or positive response that MEDCs tend to have to a hazard event. An active response to a hazard involves the following things:

1) *Modifying the effects of the event* – This reduces the level of risk e.g. hazard resistant design, dams, barriers etc.

2) *Modifying the vulnerability of an area* – This involves preparing people for the hazard. This is done through monitoring and prediction, issuing warnings, land use planning and community preparedness programmes.

3) *Modifying losses by aid and insurance* – MEDCs will be able to recover losses through insurance and government aid. However LEDCs will need to rely on international aid from charities and other governments.

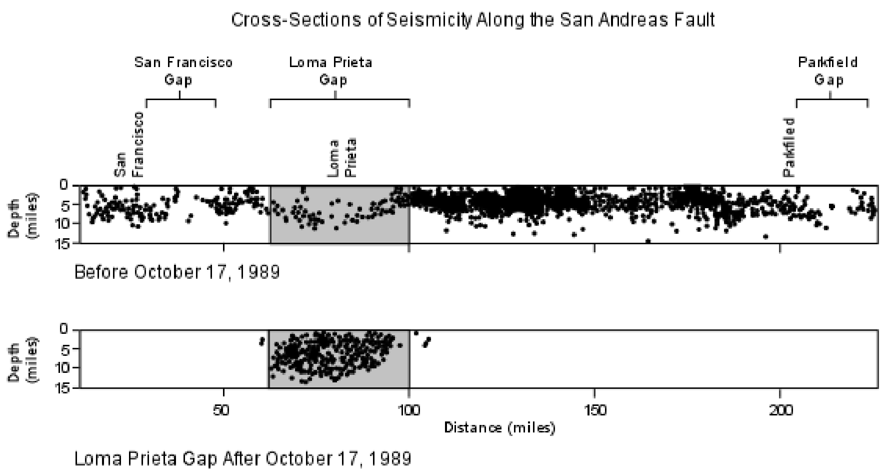
In this unit we are going to focus on number 2) Modifying the vulnerability of an area. We will do this by looking at the **monitoring**, **prediction** and **warning** strategies that can be used for earthquakes and volcanoes.

Earthquakes – Monitoring, prediction and warning

Earthquake monitoring involves the use of very expensive, modern, and highly sophisticated equipment. Crustal pressure and seismic activity are measured at Observation Stations.(See page 38) Even in the most technologically developed countries of the USA, Japan and New Zealand, earthquakes cannot be predicted with any accuracy and so much more research needs to be done.

i) Seismic gap theory

This involves recording seismic activity in a particular area over time. Where gaps in seismic activity occurs, the risk of an earthquake is greatest as pressure has been building up. A seismic gap was identified at Loma Prieta before the 1989 San Fransisco Earthquake and it was here that the epicentre was located. Today, a sesmic gap has been identified at Parkfield within the same region. This method is very effective in identifying **where** an earthquake may occur in the near future, but cannot detect **when.** It has been suggested however that this technique may lead to social and economic problems such as falling house prices, failure to attract new businesses, lack of confidence etc.



ii) Hazard mapping

A hazard map identifies vulnerable areas that are prone to earthquake activity. It can show potential risk to housing, businesses, transport networks etc. It can also map where secondary hazards such as landslides and liquefaction may occur. Again this could lead to reduced property prices and a lack of confidence and investment in the area.

iii) Ground monitoring

Physical changes in the ground will occur with the onset of an earthquake.

- the ground starts to bulge and deform
- the water table rises
- radon gas may be released

The problem lies in that these changes would occur suddenly with the onset of the earthquake and do there would be very little warning time.

iv) Observing animal behaviour

A less scientific method dismissed by MEDCs, but which saved thousands of lives in China during the 1975 earthquake. Pandas started moaning, dogs howled, horses bolted and fish jumped high out of the water. The Government decided to evacuate 1 million people just before a massive earthquake measuring 7.8 on the Richter Scale occurred.



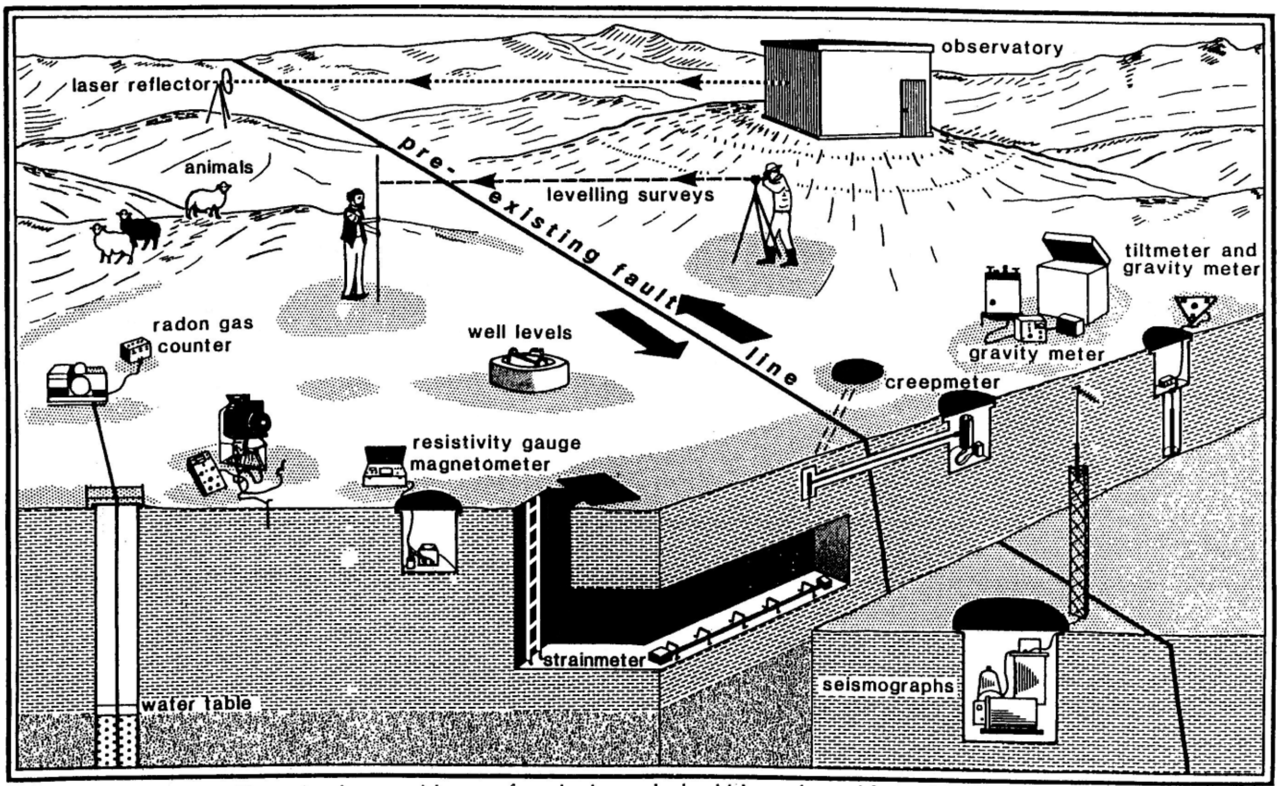


Diagram illustrating the potential range of monitoring methods which may be used for earthquake prediction along an active fault-line. Only a selection of the methods shown would be employed at any one site.

Volcanoes – Monitoring, prediction and warning

Like earthquake monitoring techniques, volcano monitoring also involves the use of very expensive, modern, and highly sophisticated scientific equipment. Once again, Japan and the USA are in the forefront while the LEDCs are way behind due to the lack of money and skill.Scientists can usually roughly predict when a volcano might erupt as, in contrast to earthquakes, a variety of environmental changes occur that can be detected and recorded.

i) Seismic activity

As well as audible rumblings, rising magma will set off a series of earth tremors that can be recorded on seismographs.

ii) Ground deformation

Rising magma will change the topography. Tiltmeters can be used to measure the amount of deformation very accurately.

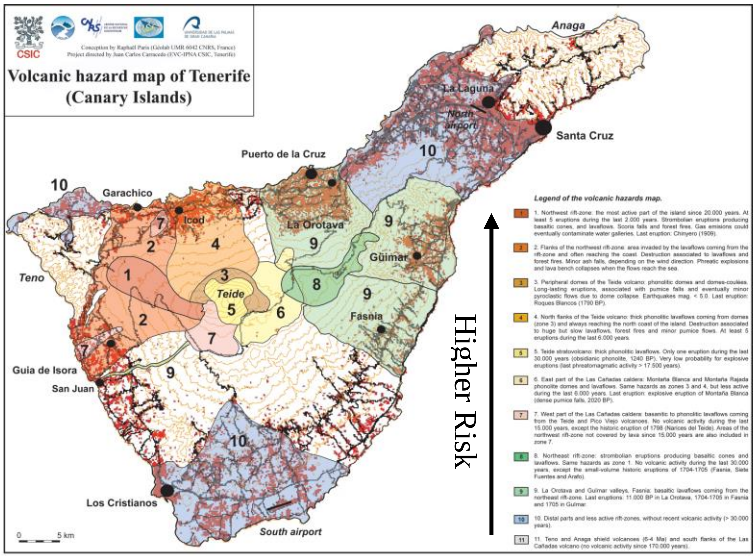
iii)Thermal monitoring

Rising magma produces an increase in temperature in the water table in the ground. These can be easily detected by remote sensing and thermal imaging from satellites.

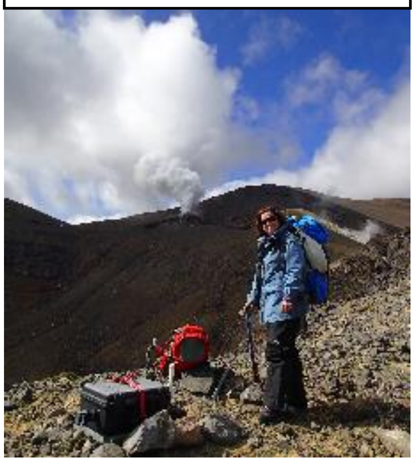
iv)Chemical and gas monitoring

Volcanic eruptions are preceded by increased emissions from gas and steam and can be detected by various measures. Water areas may show large concentrations of sulphuric acid as sulphur dioxide becomes dissolved.

v) Hazard mapping is an important part of volcano management, as in the case of earthquake management. A hazard map identifies vulnerable areas to minimise damage to property and loss of life. A planned system of land use zoning can then occur, restricting future development to safe sites in risk areas.



Monitoring volcanic gas emissions with a COSPEC remote device



So how should people respond to a tectonic hazard?

The diagram alongside shows the various stages in the preparation for and responses to any hazard. People will respond to a hazard event and rescue people, provide food and shelter etc. After this the recovery phase begins as rebuilding starts and people try to return to their normal lives. Next (certainly in MEDCs) comes the development phase where new strategies for coping are developed. After this is the mitigation phase where stronger buildings are built and new prediction and warnings techniques developed. Finally comes the preparedness phase as people and organisations ensure that they are ready for the next hazard event.

Short and long term recovery after the event

The recovery can be split into three phases which will differ depending on the wealth, organisation and planning of the country involved. In MEDCs it can take months whereas in LEDCs it can take years or even decades.

RELIEF	REHABILITATION	RECONSTRUCTION
Emergency period. An attempt is made to stop loss, damage and disruption ***quickly***. Relief is required ***immediately*** from the time the event occurs into the first couple of days or so. Involves search and rescue, providing food, water, medical care, temporary shelter. International relief agencies (Red Cross, Oxfam) have vast experience in coordinating and organising relief programmes	Actions taken in an attempt to return to normality. Will occur over the first few weeks following the disaster. Involves providing temporary housing, financial support. Usually planned locally by the Government of that country.	Permanent changes introduced in order to restore the quality of life and economic stability to its original level. Will take from weeks to even years.