ENVIRONMENTAL SCIENCE

1. LITHOSPHERIC PLATES AND THEIR MOTION

The characteristics of lithospheric plates

STRUCTURE OF THE EARTH

0 km	Crust (solid)
100 km	Asthenosphere (solid but plastic)
350 km	Mantle (solid)
2883 km	Outer Core (liquid)
5140 km	Inner Core (solid)

Oceanic Crust:

- Basaltic materials and oceanic sediments
- Dense
- Mafic
- Thin (7 km average)
- Sediment, pillow basalts, sheeted dikes, gabbro, upper mantle material attached to gabbros
- When it forms at a mid-ocean ridge, it moves away and cools, as does the mantle below it, which attaches to the base. This changes the oceanic crust into oceanic lithosphere, and increases its thickness with age. Because as it cools it becomes more dense and ‘floats’ lower in the mantle, the ocean becomes deeper as the distance from the mid-ocean ridge increases.
- Eg. Gabbro and basalt.

Continental Crust:

- Granitic materials, metamorphic rocks, sedimentary rocks, can incorporate oceanic crust
- Less dense
- Felsic
- Thick (35km average)older and more complex
- Sedimentary cover, granite schist gneiss, granulites (silica rich)
- Continental shields (metamorphic & igneous), continental platforms (thin sedimentary), fold mountains, continental rifts & rift margins
- Eg. Granite and sandstone.

The relationship between the general composition of igneous rocks and plate boundary type

There is a clear relationship between igneous composition and plate boundary type. The boundary's nature determines the origin of the magmas that form igneous rocks there.

Mantle-derived magmas give rise to the basaltic-composition rocks that form the oceanic crust.

Water released from descending plates causes partial melting of mantle material, which is further modified in the crust. This produces rocks with a characteristic andesitic composition, but a wide range of other rock types also arise.

BOUNDARY	COMPOSITION OF IGNEOUS ROCKS
Divergent	**Mafic igneous rocks –** basalt and gabbro. Rocks form as a direct upswelling of dense magmas from the asthenosphere. Normal faulting & transform faults
Convergent	*Far more diverse than at divergent boundary* **Felsic igneous rocks –** andesite, rhyolite and granite. High in silica
Conservative	Variety of igneous rocks and metamorphic rocks Eg. quartz Molten rock fills cracks to form intrusions. Strike-slip or transform faults

Location in which rock crystallises	**Extremely poor in silica**	**Relatively poor in silica**	**Intermediate silica content**	**Relatively rich in silica**
At the surface	Komatiite	Basalt	Andesite	Rhyolite
At shallow depths		Dolerite		
At intermediate depths	Peridotite	Gabbro	Diorite	Granite

The motion of plates and the types of plate boundaries

Convergent: Crustal material is destroyed as one plate slips under or over the plate moving in the opposite direction. Volcanoes produced. **SUBDUCTION ZONE & DEEP OCEAN TRENCHES.**

Oceanic-oceanic: Tonga- Pacific plate being subducted under Philippine plane.
Oceanic-continental: Nazca plate and South American plate
Continental-continental: Himalayas- form metamorphic rocks and fold mountains.

Divergent: New crustal material is produced as the plates are pulled apart and move away from each other. **MID OCEAN RIDGES OR RIFT VALLEYS.**

Conservative/transform: Plates slide past each other. Doesn't result in destruction or creation of crustal material. Site of many earthquakes.

Hypotheses used to explain how convection currents and subduction drive plate motion

Convection currents in the mantle

Radioactive decay within the earth produces convection cells within the mantle, carrying hot, molten material towards the surface of the Earth. As it cools it moves horizontally below the Aesthenosphere until it cools sufficiently to descend back into the depths of the mantle. Lithospheric plates are carried on top of these convection cells.

Slab Pull

At a subduction zone the descending plate sinks into the mantle because of its high density. The density increases because asthenosphere rock keeps solidifying onto the base of the plate.

Ridge Push

Newly formed crust is thin but thickens as it moves outwards and forms lithosphere. The density increases so the plate sinks lower into the underlying mantle and tilts.

Trench Suction

The cooling subducting plate sinks at a steeper angle than its entry angle to the trench causing the overlying plate to be dragged over the trench.

Basal Drag

A force that pulls the overriding plate at a subduction zone towards a trench.

Slab pull, ridge-push and trench suction are forces acting at plate edges, while basal drag forces act on the whole lower surface of the plate.

Continental lithosphere, which extends further into the mantle, will be more affected by basal-drag than oceanic lithosphere. On the other hand, slab-pull and ridge-push forces would have a strong effect on the oceanic lithosphere.

Forces driving plate motion

- The mantle is fluid- transverse seismic secondary waves will not pass through it.
- The core of the earth is quite hot- heat left over from the earth's formation and produced by the radioactive decay of isotopes.
- The mantle near the surface is cooler due to the loss of heat through the thick crust.
- Hot material rises and cold material sinks.
- The slab of crust at subduction zones extends a long way into the mantle.
- Mountains of heavy volcanic rocks exist along mid-ocean ridges.
- As rocks migrate from mid-ocean ridges to subduction zones they cool and become more dense.
- Denser materials sink when placed into less dense fluids.
- Plate movement is at a constant speed, implying the forces are in balance.
- Plates with large subduction edges relative to their size move more quickly than those with small subduction edges.

2. THE MOVEMENT OF PLATES RESULTS IN MOUNTAIN BUILDING

Mountain belts formed at divergent and convergent plate boundaries

Faults

If a set of rocks is brittle or particularly string the rocks will resist folding and instead the forces exerted on them during mountain building may cause them to break.

Normal Fault*:* DIVERGENT- mid-ocean ridges and sites of continental rifting
Forces are trying to stretch the crust. One is pulled up and one down

Thrust/Reverse Fault: CONVERGENT- fold mountain belts
Forces are trying to compress the crust. One side rides up over the other

Transform/strike-slip Fault: TRANSFORM/CONSERVATIVE - can occur in mountain ranges where parts of the crust are being compressed or stretched at different rates
Forces pull rock sideways. Rocks slide along away from each other

Folding

- If compression forces continue over a long period of time, rock can bend and deform, FOLDING the crust
- Shortens width and increases thickness
- Two types: synform/syncline (u shape) and antiform/anticline (upside down u shape)

DIVERGENT

Oceanic:

- Central rift valley- sea floor spreading
- Mid-ocean ridges- underwater mountain chain
- Mirror image symmetry
- Height decreases on both sides of rift as plate sinks into mantle due to density
- Slow spreading ridges have central rift valley and rugged topography
- Fast spreading ridges have lower relief, are smoother and lack a central rift valley
- Largest mountain systems on earth
- Broad and linear
- Simple mountain structure
- Shallow seismic activity
- Constantly active
- Normal & transform faulting
- Ocean sediments further from central rift form shale, chert and limestone.
- Top BASALT from pillow lava
- deeper GABBRO
- metamorphism

Continental:

- Volcanoes
- Rift valley
- Uplift produces plateaus adjacent to the rift. These plateaus slope upwards towards rift valley- seen in Africa

- Normal faults
- Shallow earthquakes
- Normal faults

- Rhyolite and basalts erupted

CONVERGENT

Ocean-ocean:

- Subduction zone
- Trench
- Volcanic island arc (grown from sea floor lava flows)
- Metamorphism
- Near plate boundaries compression-thrust faulting
- Young islands simple structure with up to 20 km crust beneath them
- Older islands have more silica and have built on the materials scraped up and erupted before, so crust beneath can be 20-30 km deep.
- Volcanoes erupt andesite, lava and ash. More explosive and viscous.
- Over millions of years it erodes and the sea floor is buried in sediments (shale and sandstone). In tropical seas limestone and coralline forms

Outer swell and trench:

Outer swell is a raised part of the subducting plate. It bulges upwards and can sometimes form islands above the surface.

Trench marks the boundary between the two plates. 50-100 km wide and an asymmetrical v-shape. Steeper side of the trench is that closest to the volcanic arc

Accretionary Prism:

Structure formed on the volcanic arc side of the trench. Forms when sediments that have been deposited in the trench together with deep sea sediments and crust from the subducting plate, are scraped off and attached to the overriding plate. Blocks of material separated by thrust faults. Material is strongly folded and deformed

Fore-arc and back-arc basins

Depositional basins may form on either side of the volcanic arc. Receives sediment from both the prism and the volcanic arc. On the other side of the volcanic arc is the back-arc basin, which also receives sediment from the volcanic arc.

Volcanic Arc

Formed from erupted material that originates from melting above the subducted plate. Volcanoes form at relatively regular intervals along the arc and at a uniform distance from the trench. Coral reefs may form in the relatively shallow waters if they are the right temperature. The volcanoes may rise 2km above sea level, and form larger islands when weathering and erosion produces sediments on their flanks. In young arcs the volcanic rocks erupted are basalts, but as the arc ages andesites become common.

Metamorphic Activity

Close to the trench, conditions of high pressure and relatively low temperatures are found- fine grained schists and slates.

Around the volcanic arc itself pressures are relatively low but, due to the igneous activity, temperatures are high- greenschists.

Ocean-continent:

- Volcanic mountain chain several hundred km inland from the trench (Andes).
- Trench
- Sediments from the upper surface of the lower plate will be scraped off to form an accretionary wedge. Mountains produced on continental plate from compression and uplift of low density wedge sediments.
- Mountains high highly folded and faulted sedimentary rocks from compression forces. Upper sections quickly erode producing large amounts of sediments going into the rivers.
- Fold and thrust belt mountains from compression
- Subducting plate forced steeply down into asthenosphere where partially melted- steam produced partly melts upper mantle →andesitic magmas
- Volcanic features: composite volcanoes, fissures, lava domes and cinder cones
- Powerful earthquakes getting deeper the further from the ocean
- Andesites characterising explosive eruptions giving way to large amounts of volcanic ash
- Rhyolite
- Granites and diorites
- Sedimentary basins
- Magma cools to form deep granite plutons
- Mountain chain characterised by volcanic and plutonic rocks rich in silica.
- Regional metamorphic rocks produced by heat and pressure forming schists and gneisses

Fold and thrust belt

Thrust faults lead to older rock being thrust over younger ones. As the distance from the centre of the fold mountain increases the temperature are less and the thrusts move relatively undeformed sedimentary layers.

Sedimentary basin and molasse

Material that accumulates in fore-arc basins consists of muds and turbidites (characteristically sorted sediments deposited from undersea avalanches of sediment called turbidity currents). Deposited in marine conditions. Sediments derived from the land are called molasse (thick sequences of sediment deposited by rapid erosion of newly formed mountains) consisting of coarse sands and silts.

Continent-continent:

- Folded mountain range (Himalayas).
- Sediments once found on ocean floor have been bulldozed up onto the continent.
- Consumes the ocean between them and as it does so it folds and deforms the oceanic sediments and these materials become part of the mountain range formed.
- Two plates 'weld' together
- Thrust faulting and folding
- Mafic- basalt and gabbro

Development of mountain range:

1. As continents approach one another the oceanic crust between them is consumed in subduction. The accretionary prism, fore-arc basin and any volcanic arcs from the subduction build up and are deformed.

2. When the ocean finally closes the continental crust of the continent with the non-subducting margin attempts to subduct under the other continental plate. Its buoyancy prevents it from subducting and so the sediments and underlaying crust become detached along a thrust.

3. The crust below the thrust continues to move forward and forses the sediments in front of it upwards. As this occurs the wedge of sediments between the two pieces of continental crust is deformed into a fold and thrust belt. At the same time weathering and erosion produce molasse sediments which are deposited in the basins on either side of the Fold Mountains. Intense deformation produces tight folding and regional metamorphism. Partial melting of sedimentary material in the core of the mountain may produce light-coloured granites.

BOUNDARY	MOUNTAIN BELT FOUND
Divergent	May be 1000's of km long. Generally very broad. Entirely volcanic in nature, and many of the mountains have flat tops. Generally found along mid-ocean ridges.
Ocean-continent convergence	Folded volcanic mountain belt running along the edges of continents. Narrow and linear, not extensively long.
Continent-continent Convergence	Complex high and very broad. High plateaus deep within the belt. Formed well inland with fragments of oceanic crust. Complex fold systems.
Ocean-ocean convergence	No mountain belts, but a series of volcanic islands forming an island arc.

3. CONTINENTS EVOLVE AS PLATE BOUNDARIES MOVE AND CHANGE

The main stages in the growth of the Australian continent

Pangaea: Was all the modern continents joined together as a supercontinent.
Rodinia was the supercontinent prior to Pangaea

Panthalassa: Was the global ocean

CRATONS:
Cratonisation involves the folding and metamorphism of material, its subsequent faulting and intrusion by granitic plutons. Only when it is eroded and beginning to acquire a covering of flat lying sediments is the material said to be cratonised.

An ancient and stable mass of continental rock.

The oldest rocks in Australia are found in cratons in Western Australia.

1. Three large cratons were established in Western Australia by 2500 mya.

2. The cratons were separated by active, linear mountain chains- mobile belts- that welded the cratons together. They were highly deformed and folded and contain metamorphic rocks and granite. The western 2/3 of modern day Australia had been cratonised. Australia was still part of Gondwana.

3. The continent developed further to the east in the formation of the Tasman fold belt. The rocks in the eastern third of Australia exhibit evidence of former island arcs and ocean trenches resulting from the subduction of an oceanic plate.

4. Sediments accumulated between the continental edge and the island arc

5. Major mountain building occurred in eastern and central Australia, supplying the sediment for the sedimentary basins developed along the eastern flank of Australia.

6. By 200mya the eastern third of Australia was cratonised.

7. Rift valleys formed down the western Australian coast between Australia and the Indian continent, beginning the breakup of Gondwana. Sea levels rose, flooding over the great artesian basin.

8. Fast spreading between India, Antarctica and Australia continued, opening up an ocean.

9. Shallow seas covered the Murray Basin

10. The continent (now the island we recognise) drifted northwards, passing over a number of mantle hot spots, resulting in a series of parallel lines of volcanoes which are younger towards the south. This includes Mount Warning.

11. Plate boundary to the north pushed against the Asian and Pacific plates causing tensional stress uplifting the Great Dividing Range to its present height.

12. Australia continues northwards.

1. First stromatolites appear
2. Banded iron formations start to be deposited
3. Ediacaran era
4. Hard shelled organisms invade land
5. First reptiles
6. Formation of the great dividing range
7. Sydney basin forms
8. Extinction of the dinosaurs
9. Formation of Bass Strait
10. Formation of the Tonga trench
11. Hot spot forms volcanoes in eastern Australia
12. Extinction of Megafauna in Australia

Plate tectonic super cycle

An entire super cycle is thought to take approximately 400my and may have major impacts on global climate.

It is thought that Pangaea formed from the collisions of previously separate continents, which have thought to come from the breakup of another previous supercontinent and so on.

1. Pangea surrounded by ocean.

2. Speading at mid-ocean ridge causes oceanic lithosphere near supercontinent to begin to subduct beneath it.

3. Produces andesitic volcanoes. This volcanism at the edges of the supercontinent causes some weaknesses in the crust there.

4. Subduction continues until subduction zone becomes choked and ceases, causing a new subduction zone to develop a few hundred km offshore. This results in a chain of new andesitic volcanoes and new continental material develops offshore. Weakness in the continental margin between the new island chain and the original supercontinent allows spreading to occur creating a trough- a back-arc basin.

5. Marginal seas and island arcs surround the supercontinent. Back-arc basins eventually fill with sediment extending the size of the supercontinent.

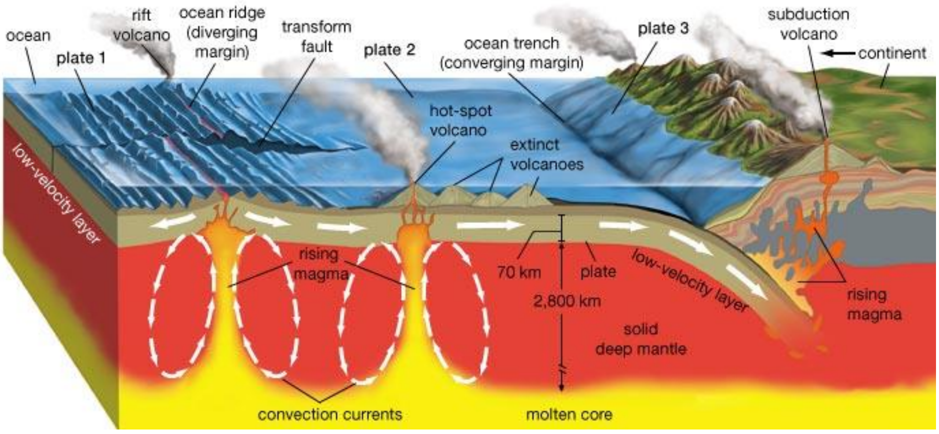
6. Due to presence of weaknesses in the zones that were once marginal seas, the supercontinent is eventually able to split up, allowing the formation of separate continents.

7. If subduction of ocean plates continue, it may bring continents together once again creating a supercontinent and thus the cycle can continue.

Pattern of growth of continent

The general trend across Australia is that the rocks become younger as we move from west to east. Australia began in the west and moved eastwards.

Plate tectonic super-cycle



Natural disasters are often associated with tectonic activity and environmental conditions caused by this activity may contribute to the problems experienced by people where earthquakes and volcanoes are currently likely to occur

Plate boundaries were discovered by plotting past earthquakes and volcanoes on a map of the world. The following predictions can be made from the plate tectonic model.

Volcanoes

Volcanoes occur mostly along the boundaries of the tectonic plates.

Volcanoes result from the upwelling of magma generated at hot locations in the mantle, and from partial melting of crust- found at plate boundaries.

- At undersea mid-ocean ridges, volcanic activity is nearly continuous but rarely builds a volcanic mountain, with the exception of Iceland.

- The great concentration of volcanic islands to the north of Australia are volcanic island arcs associated with subduction zones.

- Along the west coast of the Americas the volcanoes are also associated with subduction zones, but forming volcanic mountain ranges.

Very few volcanoes are not associated with a plate boundary, like Hawaii, which lies on a 'HOT SPOT' in the mantle below. A **hot spot** is a place where the crust is thin and allows magma to rise.

As the pacific plate moves slowly north-west, the stationary hot spot creates new volcanoes in a line to the south east.

Earthquakes

Earthquakes also frequently occur along the plate boundaries.

Earthquakes are caused by sudden movement of rocks that are under stress, found at plate boundaries, where sections of rocks are being forced to move against each other.

Rocks that are under stress can frequently adjust to the stress by folding or sliding. However, if sections lock up, stress may be released by the rocks fracturing, creating sudden large movement- earthquakes.

- At divergent boundaries there are frequent minor tremors.

- At subduction zones earthquakes are less frequent but much more powerful. Depth focus of the earthquake deepens as the plate descends into the mantle.

- Conservative boundaries can produce the most destructive earthquakes at a transform fault, being very powerful with a relatively shallow focus.

Earthquakes can also occur at the centre of a plate- **intraplate earthquakes.**
They are generally of a less destructive power and occur very infrequently.

Impacts of earthquakes on natural and built environments

Collapse of structures such as buildings and freeways:

Shockwaves from earthquakes cause vibrations within the earth's crust. Buildings crumble and collapse as the shaking of the crust shakes the foundations of buildings. Landslides and liquefaction of unconsolidated sediments can wipe out many buildings. Surfaces may literally lift structures as they pass or shift structures sideways.

Environmental effects:

Measured by the Mercalli Scale:

I- Not felt
II- Felt by some
III- Vibrations like a passing truck
IV- Windows rattle, crockery disturbed
V- Felt by all
VI- Damage to chimneys and walls
VII- Major damage on poorly built constructions
VIII- Sand and mud ejected
IX- Buildings shifted off foundations, ground cracked
X- Landslides on steep slopes, wooden buildings destroyed
XI- Earth slumps, fissures in ground, few buildings remain
XII- Total damage, waves seen on ground surface

Shockwaves from earthquakes are of three main types:

1. P-waves are compression waves.
2. S-waves are transverse waves.
3. L-waves are surface waves and can be transverse or elliptical. The elliptical waves are the slowest, but often the largest and most destructive, of the wave types caused by an earthquake.

Factors affecting intensity include the location of the focus, the triggering mechanism, the quantity of energy released and the nature of the local geology.

The magnitude of an earthquake is related to the amount of strain energy released, as recorded by seismographs. Magnitude is measured on the Richter scale.

Hazards associated with earthquakes

- Fire

- The most casualties come from collapsing structures caused by ground motion

- Damaged vehicles

- Crevasses

- In hilly or mountainous areas, earthquakes can trigger landslides, mudslides or avalanches covering entire villages.

- Tsunamis are a major hazard with undersea earthquakes, which can change the level of the ocean floor by several metres and displace an enormous volume of water. The waves produced contain the energy of the earthquake as it lifts up to 14 kilometre of ocean above it. It travels very fast over the open ocean, and upon reaching shallow water, the front of a tsunamis wave-set slows down while the back catches up to produce a massive wall of water. Tsunamis devastate low lying coastal areas. Houses and other structures are usually hit by a wall of water from the ocean and again as the water rushes back out to sea. Floating debris kills people and destroys property.

Intra-plate and plate margin earthquakes

The Australian continent lies entirely within the Australia-India plate, and so it does not experience plate boundary processes, which account for 90% of all earthquakes.

Intra-plate earthquakes don't occur near a plate boundary but in the middle of one, like in Australia. They are usually caused by compressive stress in rocks. The Newcastle earthquake (5.6 magnitude) was an example of one, which was most likely caused by readjustments along an old fault running through Newcastle under strong easterly compression from the expanding Pacific ocean floor.

Australia has three distinct regions of earthquake activity. These are:

- the Eastern region, covering the eastern highlands and coastal areas
- the Central region, extending from near Adelaide to the Simpson Desert
- The Western region, encompassing several distinct zones.

Some intra-plate earthquakes may be related to the stress at plate boundaries and to temperature changes in the lithosphere caused by processes in the mantle.

Hazards associated with volcanoes and the impact of these on the environment, people and other living things

Explosive eruption: violent causing many deaths.

Lava flows: Most are slow moving and may destroy farmland, infrastructure and animal habitats as its progress is rarely stoppable.

Highly viscous lava tends to block volcanic vents and lead to explosive eruptions. High temperature, low viscosity lava flows freely and is often associated with hot spot volcanoes and sea floor rifts. These lavas do not usually endanger human life because there is time for evacuation. However all property in their path is destroyed by the lava.

Ash Clouds: Settles over wide areas suffocating animals and people. The weight causes buildings to collapse and aircraft engines can be affected. Can bury vegetation and close roads. People can suffer respiratory problems. Often the ash turns into a very hard surface after it is wet and this can inhibit the germination of plants. The ash reflects more light causing local changes in climate.

Lahars: Glaciers melted or lakes released during an eruption can mix with ash to form a lahar which can rush down gullies and valleys destroying everything in its path. Because they follow creek lines they can cause many casualties in populated areas around the base of volcanoes. Strips soil and slows revegetation. Erosion can produce gullying and further erosion.

Pyroclastic Flows: A cloud of red hot ash buoyed by poisonous gases so that it acts as a liquid, pouring down the mountain at 100km/hr like a glowing avalanche.

Suffocation on toxic gases: Toxic or suffocating gases like co2 can fill low lying areas and suffocate all animals reducing oxygen content in air.

Physical, chemical and biotic characteristics of a volcanic region and why humans would inhabit such regions of risk

- Volcanic mountains increase rainfall by forcing moist air to rise and form clouds.
- May be large areas of bare ground due to lava flows and ash falls. Terrain may be rough and rugged.
- Soils are young with low humus levels but high levels of minerals making them extremely fertile.
- Biologically diverse with lots of different habitats. High slopes have glacial and snowy alpine zones and lower down is rainforest, grassy plateaus, open forest, misty ravines and boggy marshes.
- Recent ash falls and lava flows give opportunities for coloniser plants (moss, ferns and lichen).
- Gradually soils develop, streams evolve and area changes from a bare lava flow to a mature forest which is then wiped out and the process starts again.

Humans

- Fertile soil and good water supply allows food productivity to be high, which attracts poorer human communities that have to produce their own food.
- Many volcanoes only erupt once or twice per century, leaving several generations to safely farm the land between eruptions.
- In places like Italy the eruptions are much more frequent, but usually predictable, leaving time for evacuation.
- Volcanic landscapes have aesthetic attraction for people. Mountains create beautiful scenery and symmetrical volcanic cones have been important to many cultural beliefs.

- Elevation of volcanoes can produce particular environments, cooler than nearby areas at lower altitudes.

- Mineral deposits attract mining.

- Draw tourists because of their scenery and island cultures or because they provide good ski slopes.

For many people the rewards to be found living near a volcano outweigh the risks.

Shield Volcanoes

- Formed from 'runny' liquid magma (non viscous)
- Flows easily down slopes
- Magma is mafic (basaltic)
- Low in silica content
- Gentle slopes

Composite Volcano

- Alternate mafic and felsic eruptions
- Felsic (quartz rich) - violent
- Mafic(quartz poor)- non violent
- Cone shaped

Methods used for the prediction of volcanic eruptions and earthquakes

Tsunamis

Satellite radar systems are now able to detect a tsunami before it reaches land. A warning system is established in many parts of the world, but not in many risky poorer less developed areas.

Earthquakes

Accurate Land Surveys: Laser beams or satellite radars can detect movement of just a few millimetres, horizontally and vertically. These movements indicate that stresses are building within the crust.

Strain Gauges: Directly measure the forces building up within the rocks.

Electrical Measurement: Monitors changes to the electrical conductivity of rock, which changes if rocks are under pressure, tension or compression

Geiger meters: Monitors the release of radon gas. As stresses build up in rocks, tiny fractures occur, releasing it.

Seismometers: Detect small movements along faults, indicating stress is building up to a 'big one'.

Tilt meters: Measure flexing of the surface

Ground water level and temperature measurement: provide information about changing stresses within the rocks

Volcanoes

Easier to predict than earthquakes. Even without technology, before an eruption there may be rumblings, tremors and small emissions of steam, gases and ash.

Technology allows data to be collected remotely, reducing risk.

Direct observation: changes in or new cracks in the ground, changes in steaming from vents, death or damage of plants

Historical observations: Used to build up an eruption history.

Seismometers: Monitors vibrations- occur as magma chambers deep underground fill up.

Laser Beam Surveys: Measure changes in the shape of the mountain. Many volcanoes ‘bulge’ as magma chambers fill and pressure builds.

Gravity Meters: Measures slight changes to the local gravitational field- mass density changes as magma chambers fill

Chemical Gas Analysers: Monitor changes in co2 emissions. Sulphur dioxide and hydrogen gases escaping from vents.

Heat Flow Meters: Measure changes in the heat energy below ground. Indicates an approaching eruption.

Research into reliable prediction of earthquakes and volcanic activity

Many lives could be saved if people were given warnings prior to a large volcanic eruption- there are large populations in many volcanic and earthquake prone areas. People would have a chance to save precious possessions if they had enough warning before a major eruption.

Research is expensive, and many countries can't afford it. If eruptions could be accurately predicted there would be less unnecessary evacuations for communities and the communities with in turn have more faith in the ability of authority to predict these events.

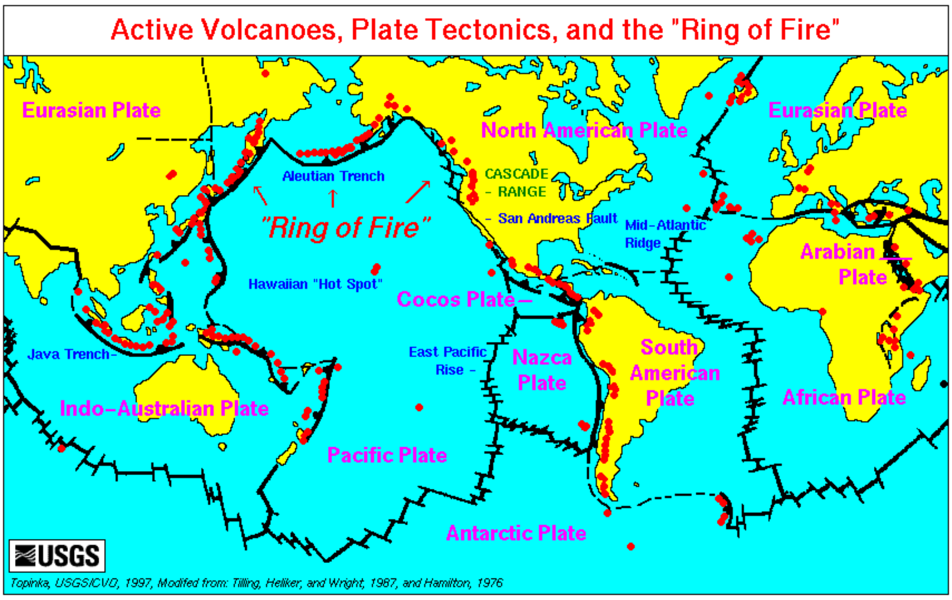
Technology used to measure movement at collision boundaries

Creep meter: Measures progressive increasing changes in position between two points on opposite sides of a plate boundary

GPS: Uses satellites which continuously transmit signals to ground sites around the earth. Using signals from a least 4 satellites a precise position of a grand site can be made. Repeated measurements will pick up changes in the position of the Earth's crustal plates and inflation on the flanks of volcanoes.

Laser Reflectors: Make accurate measurements of the time taken for a laser beam to travel a measured distance. This method can detect very small changes in position across a plate boundary.

Plate boundaries


Active Volcanoes, Plate Tectonics, and the "Ring of Fire"

Topinka, USGS/CVO, 1997, Modified from: Tilling, Heliker, and Wright, 1987, and Hamilton, 1976

CASE STUDY- Indian Ocean Earthquake and Tsunami

Mega thrust undersea earthquake occurred 26th December 2004. Epicentre off west coast of Sumatra, magnitude 9.3. Triggered a series of tsunamis devastating the coastlines of most of the landmasses bordering the Indian Ocean. Indonesia, India, Sri Lanka and Thailand were the worst hit.

Earthquake:

Shallow focus of about 10km. Fault surface slipped 15m along the subduction zone where the Indian plate subducts beneath the Burma plate. Took place in two phases and then lots of aftershocks triggering others as far as Alaska.

Tsunamis:

The sudden vertical rise of the seabed by several metres displaced massive volumes of water, forming a series of tsunamis striking the coastlines of the Indian Ocean. They rose up to 30 m in some areas while travelling inland.

Radar satellites recorded waves 2 hours after the earthquake, but couldn't act as a warning as the data took hours to analyse.

It took between 15 mins and 7 hours for the waves to hit the coastlines, destroying communities.

Recurrence:

Surrounded by 4 major tectonic plates, Indonesia is prone to earthquakes and so subsequently tsunamis.

Most of the stresses built up in the immediate region were released during the quake, so it is unlikely for another major earthquake in the region in the near future to occur, but stresses will start building up again.

This doesn't mean another earthquake won't occur further north or south- movement of plates may also add stress along other tectonic boundaries causing tectonic activity in other regions.

Prediction:

First warning sign of tsunami is earthquake itself, but tsunamis can hit areas the earthquake wasn't felt. The sea temporarily recedes from the coast, allowing minutes for people to get to higher ground.

Tide Gauges- Measures height of sea surface

Satellites- Measures height of ocean surface by the use of electromagnetic pulses sent down to the ocean's surface by the satellite.

The DART system- Deep ocean assessment and reporting of tsunamis system. Deployed in Pacific Ocean giving detailed information about the waves while still far offshore. Buoy stations.

Solutions to minimise disastrous effects:

Raising awareness- many local peoples of the countries affected were not aware of the tsunamis signs, and tourists urged people to move to higher ground.

Signs-

- *Strong earthquake near the coast*
- *Noticeable rapid rise or fall in coastal waters*
- *Loud roaring noise from ocean*

Building evacuation plans should be known in low lying coastal areas prone.

If you are in a coastal area and feel a strong earthquake-

- *Drop, cover and hold on to protect from earthquake*
- *When shaking stops move quickly to higher ground away from the coast*
- *Be prepared for aftershocks*

4. PLATE TECTONICS AND CLIMATE

Possible effects of explosive volcanic activity on global and local climates

Local

Very ash rich eruptions are called 'plinian' eruptions, which can hurl ash, dust and gases 30 km or more into the upper atmosphere.

Almost total darkness may prevail for several days, and there may be sudden rainstorms from condensing water vapour. The rain may be more like acid mud. The upwelling of ash creates static electricity, so there may be violent lightning storms.

Global

Plinian eruptions can hurl material into the stratosphere, above the troposphere where clouds form and weather occurs.

Most particles fall down under gravity but fine dust can remain suspended for years.

Aerosols are also formed, microscopic liquid droplets suspended in the air, formed from sulphuric acid. This can spread worldwide. They reflect and scatter incoming light and ash can block radiation.

Initially, dust and aerosols block and reflect and scatter sunlight, so that less radiation reaches the surface, lowering global average temperatures. All volcanic eruptions emit vast quantities of CO_2, a greenhouse gas, so when the cooling effect disappears, warming will occur.

Plate movement and climate:

When there is a single supercontinent, climate is colder and drier with lower sea levels. This is because volcanic activity is at a minimum (less subducting and rifting) so CO_2 levels are less.

When there are continents split up there is much more rifting and subducting, increasing CO_2 levels.

Impacts of volcanic eruptions on global temperature and agriculture

The potential impacts of volcanic eruptions on global temperature:

The injection of sulfur dioxide into the stratosphere converts to sulfuric acid aerosols that block incoming solar radiation and contribute to ozone destruction. The reduction in solar radiation can cause global cooling. The plume of ash from an eruption causes an increase in the amount of sunlight reflected by the Earth's atmosphere back to space causing the surface of the planet to cool.

The potential impacts of volcanic eruption on agriculture:

Volcanic eruptions have the potential to devastate agricultural activity. Areas close to the erupting cone can be destroyed by lava and mud flows. Poisonous gases can kill herds of stock. Areas further from the cone can be covered in thick layers of pyroclastic debris. Volcanic soil, is however very fertile, so with time it will benefit agriculture. Crops can fail. Famine.

Cold days need more energy to stay warm. Crops may not ripen and the price of some fresh foods would increase due to resulting shortages, energy costs would rise and rainfall patterns would possibly change. The poor would suffer most if this were to happen as the prices of essential items increased beyond their ability to pay for them.