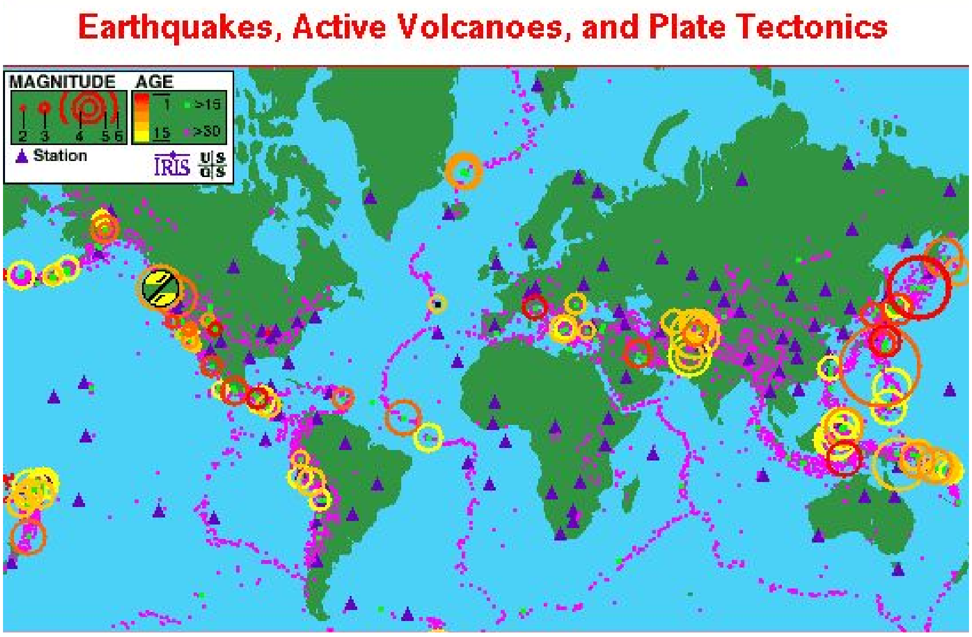
CAIE Geography Pre-U

3A: Tectonic Hazards

Detailed Notes

Distribution

A **hazard** is a potential threat to human life and property. The Earth consists of many moving plates, volcanoes and earthquakes are as a result of these moving and interacting plates. Most tectonic activity occurs along the plate boundaries.



Geophysical hazards occur **near plate boundaries**. These plates move at different speeds and directions which can cause collisions, earthquakes and volcanic activity as shown in the map above.

Earthquakes can also occur near the middle of plates (called **intra-plate**). The causes of this are not fully understood but it is assumed that plates have **pre-existing weaknesses** which become reactivated, forming seismic waves. For example, an intraplate earthquake may occur if solid crust, which has weakened over time, cracks under pressure.

Volcanic hotspots, such as the Ring of Fire, are also situated amongst the centre of pates. This is a **localised area of the lithosphere** (Earth's crust and upper mantle) which has an unusually high temperature due to the upwelling of hot molten material from the core. (First theorised by **Tuzo Wilson** in 1963)

At hotspots, such as the Hawaii hotspot, **magma** rises as plume (hot rock).

Usually, the most powerful earthquakes occur at **convergent or conservative** boundaries.

Explanation and causes of tectonic hazards

The evidence to support the plate tectonic theory

Continental drift is a theory that explains how continents shift positions on the Earth's surface. It was thought of by **Alfred Wegener in 1912**. It suggests that the continents were once all joined together in a supercontinent, known as **Pangea**, which then broke apart with the movement of the plates. Also, if you look at a map of the world you will see that some continents appear as if they could **fit together**. For example, the East side of South America could fit with the West side of Africa. This shows that the continents were once joined together.

There are **ancient rock outcrops that are continuous** from Africa to South America showing that they were once joined. There are also many **fossils** which have been found on separate continents and nowhere else which suggests that they were once connected. For example, fossils have been found in India and Australia but nowhere else.

Palaeomagnetism has provided the strongest evidence for the plate tectonic theory. **Magnetic minerals** within rocks in places such as Alaska are orientated in such a way that they could have only been laid down when they were located near the equator. Magnetic minerals in South America and Africa are also oriented almost identically showing they were once joined. However, the evidence that palaeomagnetism provides in terms of **sea-floor spreading** is the most remarkably successful.

Mid-ocean ridges are areas on the seafloor where the plates are moving away from each other and magma is rising up to create a new ocean floor. The patterns of the orientation of magnetic minerals on either side of the ridge are mirror images of each other, thus supporting the theory that the plates move away from each other. Also throughout history, the orientation of earth's magnetic field has alternated. The minerals in the seafloor by ocean ridges are in layers of alternating direction showing that new rock was being formed throughout history.

Mechanisms for plate movement

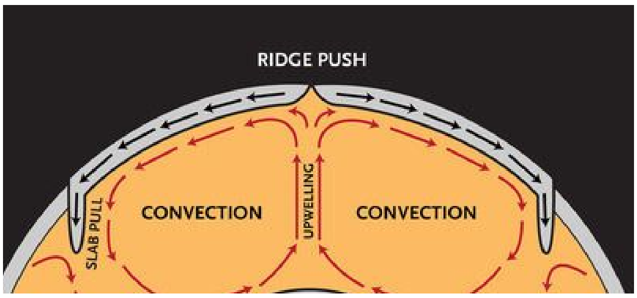
There are two different types of crust and they consist of different rocks:

- **Oceanic** – Low density of rock, mainly basalt, thin, newly created.
- **Continental** – High density of rock, mainly granite, thick, old.

The **density** of the plate will determine whether the plate subducts or is forced upwards. This will determine the **landscape** and **hazards** the margin is vulnerable to.

There are different **mechanisms** that could cause plate movement:

- **Mantle Convection** - Radioactive elements in the core of the Earth decay which produce a lot of **thermal energy**. This causes the lower mantle to heat up and rise, as the magma rises it cools down and becomes more dense and begins to sink back down to the core. These are **convection currents**. These convection currents push the plates.
- **Slab Pull** - Old oceanic crust (which is the most dense plate) will submerge into the mantle. This pulling action drags the rest of the plate with it. (It was first theorised by **Dan McKenzie**)



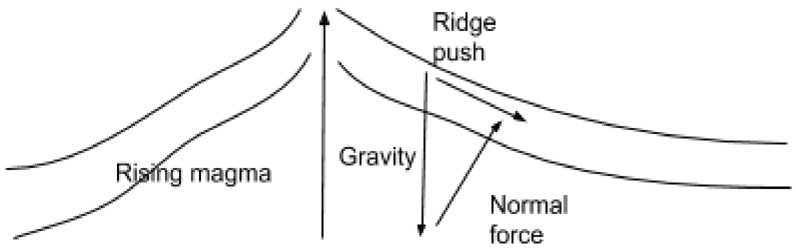
It is important to note that tectonic movement isn't fully understood. Previously, **convection currents** were thought to be the primary cause of plate movement. However, researchers now believe that **Slab Pull** is the **primary mechanism** for plate movement; convection currents seem too weak to move massively dense plates.

Watch this video on the mechanisms for plate movement.

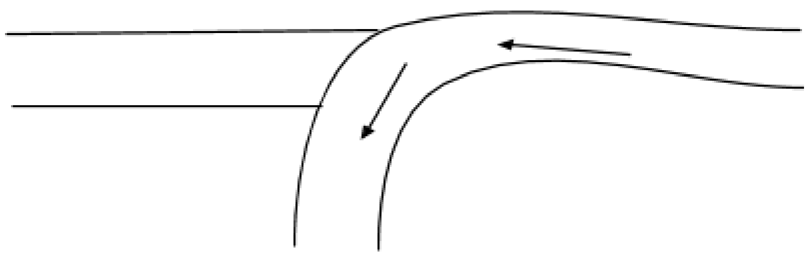
Plate margins

Different processes occur at different plate boundaries, these create different physical features. Watch this video on plate margins.

At **mid-ocean ridges**, the upwelling molten magma is very hot and not as dense as the rest of the seafloor. The **subsequent cooling and subsiding** of the newly formed rock have been shown to **exert pressure** on the plates helping to drive the spreading that has started due to the new material rising up in between two plates pushing them apart. This is known as **ridge push**.



At a **destructive margin**, a cooler, denser plate subducts under the lighter plate. This **pulls the rest of the plate along** and is known as **slab pull**.

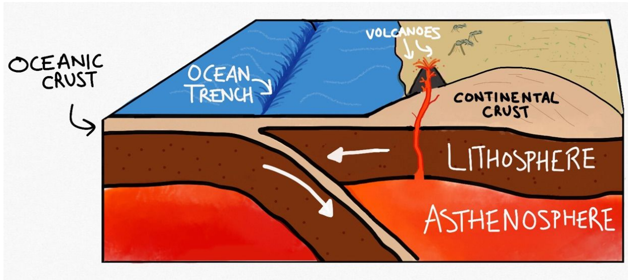


<table>
<tr><th colspan="2">Destructive plate boundaries</th></tr>
<tr><td>

Continental and oceanic:

- Denser oceanic plate **subducts** below the continental.
- The plate subducting leaves a deep **ocean trench**.
- **Fold mountains** occur when sediment is pushed upwards during subduction.
- The oceanic crust is melted as it subducts into the asthenosphere.
- The extra magma created causes **pressure** to build up.
- Pressurised magma forces through weak areas in the continental plate
- Explosive, high pressure volcanoes erupt through the continental plate, known as **composite volcanoes**.

</td><td>

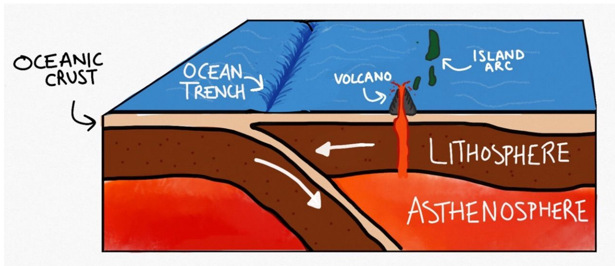


</td></tr>
<tr><td>

Oceanic and oceanic:

- Heavier plate **subducts** leaving an ocean trench. Fold mountains will also occur.
- Built up pressure causes **underwater volcanoes** bursting through oceanic plate.
- Lava cools and creates new land called **island arcs**.

</td><td>

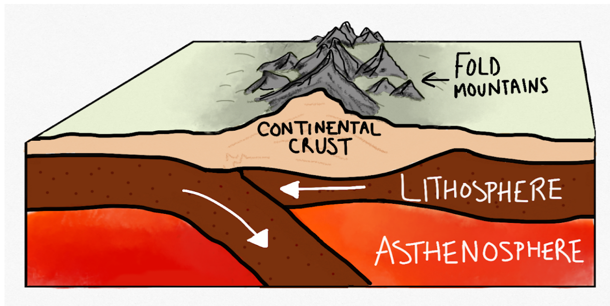


</td></tr>
<tr><td>

Continental and continental:

- Both plates are not as dense as oceanic so lots of **pressure builds.**
- Ancient oceanic crust is subducted slightly, but there is **no subduction of continental crust.**
- **Pile up** of continental crust on top of lithosphere due to pressure between plates.
- **Fold mountains** formed from piles of continental crust.

</td><td>

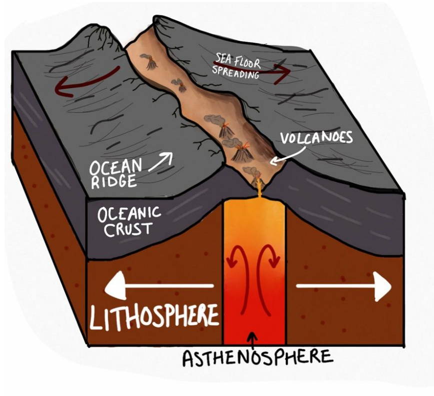


</td></tr>
</table>

Constructive plate boundaries

Oceanic and oceanic:

- Magma rises in between the **gap left by the two plates separating**, forming new land when it cools.
- Less explosive underwater volcanoes formed as magma rises.
- **New land** forming on the ocean floor by lava filling the gaps is known as **sea floor spreading** (as the floor spreads and gets wider).

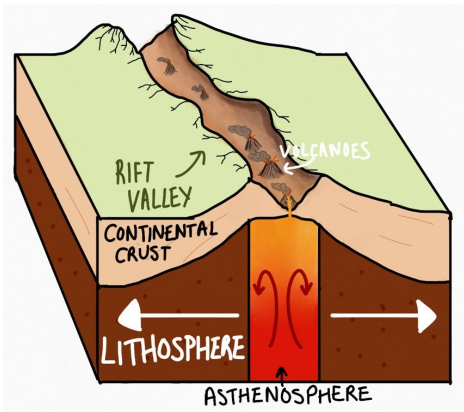


Evidence

There is sufficient evidence to prove plate movement, and **sea floor spreading** (theorised by **Harry Hess** in the 1940s) provides some of this proof. **Paleomagnetism** is the study of rocks that show the magnetic fields of the Earth. As new rock is formed and cools the magnetic grains within the rock align with the magnetic poles. Our poles (North and South) **switch** periodically. Each time these switch the new rocks being formed at plate boundaries **align in the opposite direction** to the older rock. On the ocean floor either side of constructive plate boundaries, Geologists observed that there are **symmetrical bands** of rock with **alternating bands of magnetic polarity**. This is evidence of sea floor spreading.

Continental to continental:

- Any land in the middle of the separation is forced apart, causing a **rift valley**.
- Volcanoes form where the magma rises.
- Eventually the gap will most likely fill with water and separate completely from the main island.
- The lifted areas of rocks are known as **horsts** whereas the valley itself is known as a **graben**.



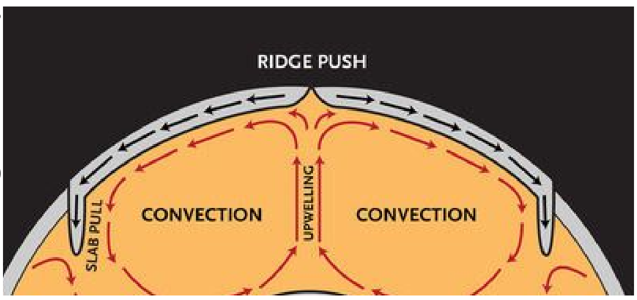
There are further forces influencing how convergent boundaries occur -

Ridge push:

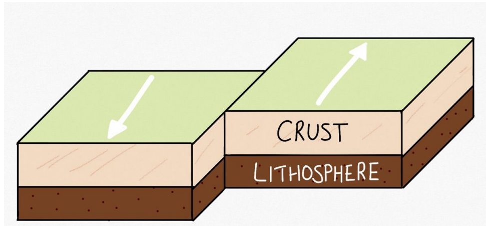
The **slope** created when plates move apart has **gravity acting upon it** as it is at a **higher elevation**. Gravity pushes the plates further away, widening the gap (as this movement is influenced by gravity, it is known as **gravitational sliding**).

Slap pull:

When a plate **subducts**, the plate sinking into the mantle **pulls the rest of the plate** (slab) with it, causing further subduction.

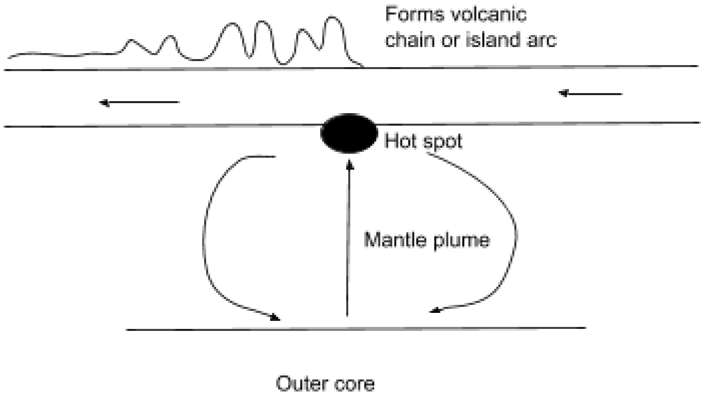


Source: CK-12 Foundation

Conservative plate boundary	
Between any crust, the **parallel plates** move in **different directions** or at **different speeds**. No plates are destroyed so no landforms are created. When these plates move, a lot of pressure is built up. On oceanic crust, this movement can displace a lot of water. On continental crust, **fault lines** can occur where the ground is cracked by the movement.	

Hot spots

Hotspots are areas of volcanic activity that are **not related to plate boundaries**. Hot **magma plumes** from the mantle rise and **burn through** weaker parts of the crust. This can create **volcanoes and islands**. The plume stays in the same place but the **plates continue to move**, which sometimes causes a **chain of islands** (such as Hawaii). Watch [this video]() on hot spots.



Supervolcanoes

Deposit material of a volume greater than **1,000 cubic kilometres**. Once a supervolcano has erupted a depression in the earth's surface, called a **Caldera**, is formed. An example of a supervolcano is **Yellowstone** in the USA which has had three massive eruptions. If Yellowstone erupts it will be a **million times more powerful than an atomic bomb** and **10,000 times the size of the Mount St Helens eruption**. This would produce ash which would surround the whole planet plunging it into an ice age and damaging buildings, infrastructure and crops. Watch [this video]() on supervolcanoes.

Different Plate Boundaries

At plate boundaries, different plates can either move **towards each other** (**destructive** plate margin), **away from each other** (**constructive** plate margin), or **parallel** to each other (**conservative** plate margin). Different landforms are created in these different interactions. This spider diagram outlines what landforms and processes occur at the boundaries.

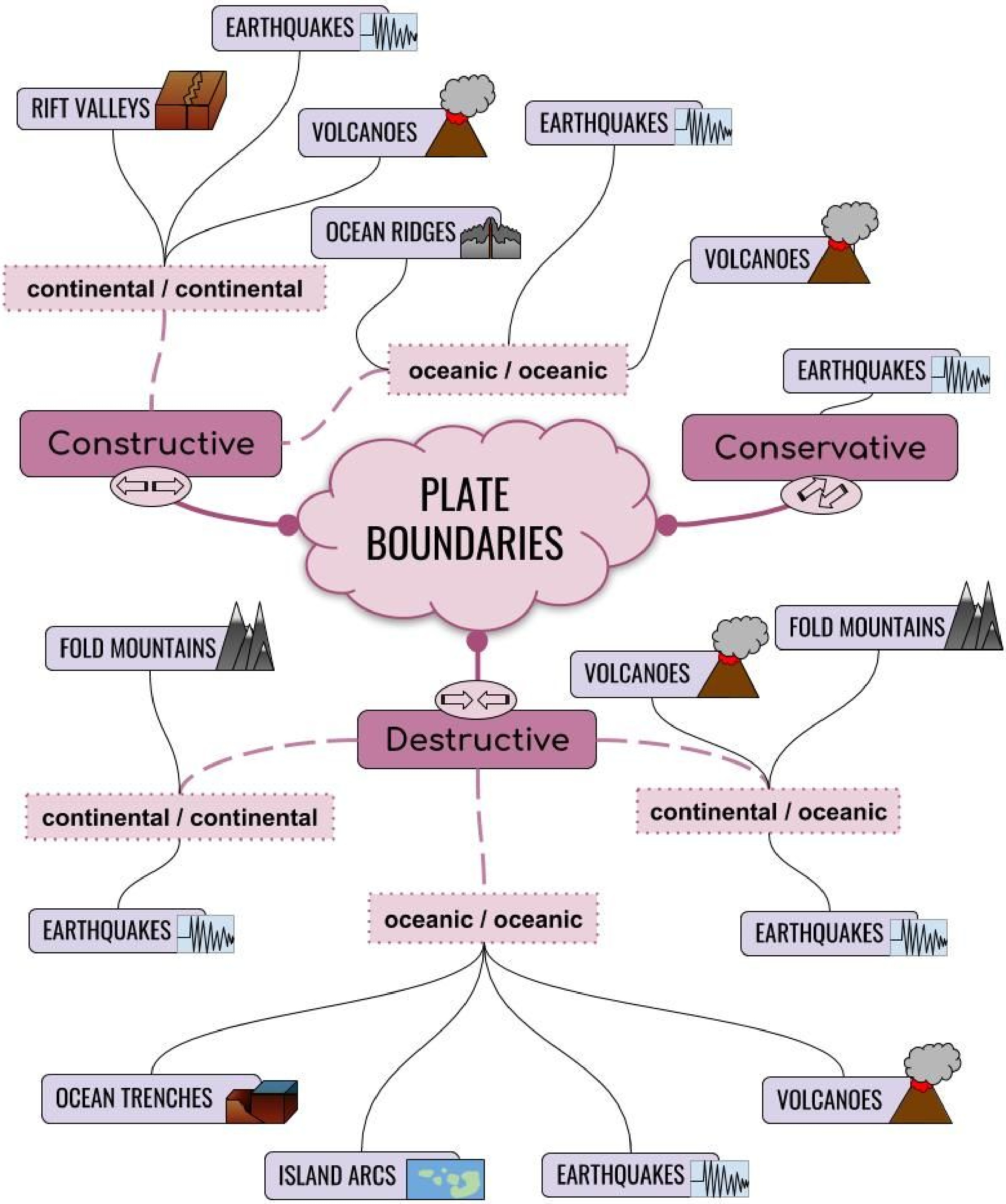


PLATE BOUNDARIES
Constructive
continental / continental
RIFT VALLEYS
EARTHQUAKES
VOLCANOES
oceanic / oceanic
OCEAN RIDGES
EARTHQUAKES
VOLCANOES
Conservative
EARTHQUAKES
Destructive
continental / continental
FOLD MOUNTAINS
EARTHQUAKES
continental / oceanic
VOLCANOES
FOLD MOUNTAINS
EARTHQUAKES
oceanic / oceanic
OCEAN TRENCHES
ISLAND ARCS
EARTHQUAKES
VOLCANOES

Consequences and impacts

Types of a volcanic eruption

- **Hawaiian eruption**: Fluid basaltic lava is thrown into the air in jets from a vent. This can last for hours or days. Flows of lava can travel for miles before they harden because they are so fluid. An example of a Hawaiian eruption is the 1959 eruption of Kilauea.
- **Strombolian eruption**: Distinct bursts of fluid lava from a magma-filled summit conduit. These bursts occur every few minutes and are caused by the bursting of large bubbles of gas. Strombolian eruptions can also form lava bombs and lava flows. They are the least violent of explosive eruptions.
- **Vulcanian eruption**: Short, violent, relatively small explosion of viscous magma. It is caused by the explosion of a plug of lava or from a rupture of a lava dome. These eruptions produce tephra, ash clouds and pyroclastic density currents.
- **Plinian eruption**: These are the largest and most violent of all eruptions. Columns of gas and ash can rise 50km into the sky. Can also form lava bombs and pyroclastic density currents. An example of a Plinian eruption in the 1980 Mount St Helens eruption.
- **Surtseyan eruption**: When magma interacts explosively with water. This usually occurs when an undersea volcano breaks the surface of the water. It creates columns of ash and steam.

Hazards from volcanoes

- **Pyroclastic flows**: High-density mixture of hot, fragmented solids and expanding gases that travel over 100km/hr down the side of a volcano at 200-700°C.
- **Lava flows**: These are the least hazardous products of a volcano. They are more dangerous to property than to people as they normally travel so slowly.
- **Tephra**: Fragmented material ejected by a volcano. Can include rocks, lapilli and ash. These can be dangerous to aeroplanes, create poor visibility, disrupt electricity and cause lightening.
- **Lahars**: Similar to pyroclastic flows but contain more water so are similar to mudflows. They are extremely dangerous, especially to those living in valleys.
- **Jokulhlaups**: Where there is a violent, short-lived and sudden increase in the discharge of glacial meltwater due to a volcanic, normally subglacial, eruption.
- **Toxic gases**: Cause acidic erosion and asphyxiation. Between 1900 and 1986, 3% of all volcano-related deaths were from toxic gases.

Hazards from earthquakes

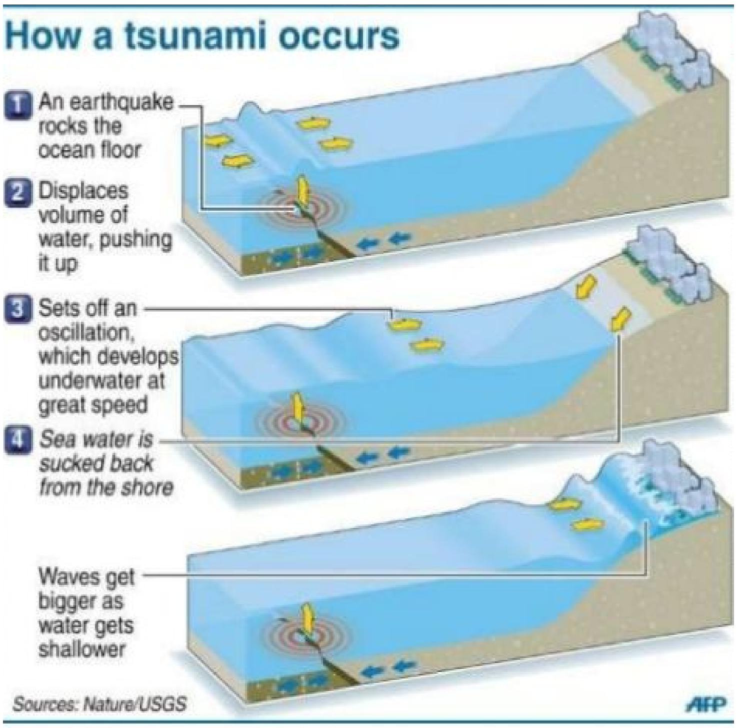
Ground shaking: Causes stress in structures and destabilization of cliffs and sloping ground. Depending on the velocity, acceleration and displacement of the ground shaking, buildings can collapse. This can cause injury and death as well as the need for rebuilding after the earthquake

Liquefaction: Seismic activity agitates the ground material of certain types. The loose material within the ground begins to compress. The water within resists the change and so pressure builds. Grains of material become buoyant and float in the water. This new ground composition can **no longer support the same amount of weight** and so many buildings sink. In 2011 in Christchurch, there was a settlement of land and buildings by 200mm. Watch this video on liquefaction.

Landslides: When an incline with relatively large masses of material is supported by soil that will easily soften under strain creates areas of land that are prone to landslides. This can damage infrastructure, cause injury and block roads. The blockage of roads can make it difficult for rescue and aid to reach certain areas, especially in LICs.

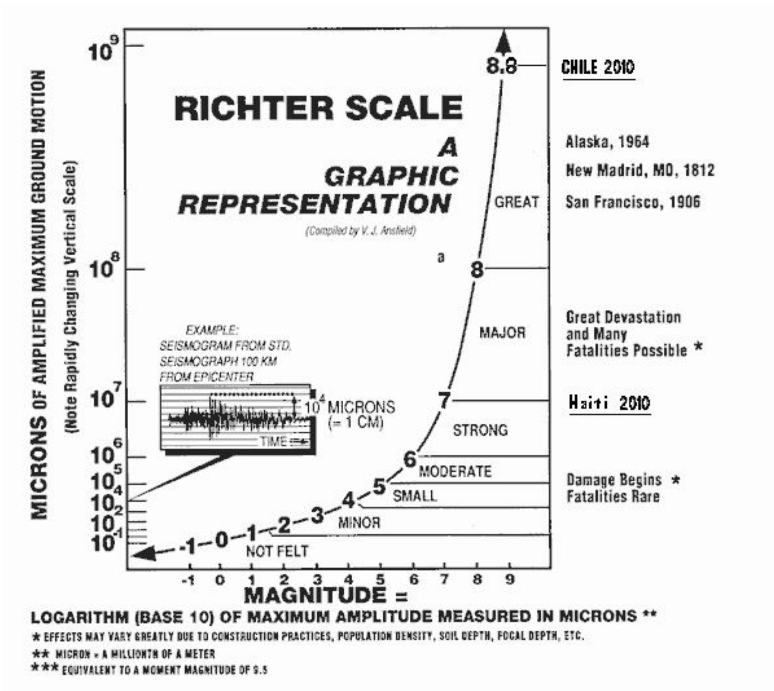
Tsunamis

- When an oceanic crust is jolted during an earthquake, all of the water above this plate is **displaced**, normally upwards
- This water is then pulled back down due to gravity. The energy is transferred into the water and travels through it like a wave.
- The water travels fast but with a low **amplitude** (height).
- As it gets closer to the coast, the sea level decreases so there is friction between the sea bed and the waves.
- This causes the waves to slow down and gain height, creating a wall of water that is on average 10 feet high, but can reach 100 feet.
- After the earthquake, the remaining stagnant water increases the transmission of diseases, especially if there are dead bodies in the water. Watch this video on tsunamis.



Measuring the magnitude of earthquakes

The **Richter scale** is a **quantitative** measure of the size of an earthquake. The **logarithm of the amplitude of the largest seismic wave**, which has been measured using a seismograph, determines the earthquakes magnitude. This means that each increase in number in the Richter scale gives a ten-fold increase in the magnitude of the earthquake.



The **Mercalli scale describes the effects of the earthquake**. The scale list several effects from the intensity of the earthquake for example not felt by many, felt by everyone with some windows broken, some well built wooden structures destroyed. The Mercalli scale is more **subjective** than the Richter scale and not as widely used.

Management and mitigation

Prediction and risk identification

- **Seismographs**: Detect the length and strength of an earthquake although cannot predict if an earthquake is about to occur. Earthquake can also be precursors for volcanic eruptions so seismographs can predict volcanic eruptions. They can also be used to detect any ground deformation/swelling that occurs before an eruption.
- **Gas emissions**: Measure gas emissions in vents or in the area surrounding the volcano. The **amounts and ratios of gases** such as SO_2, CO_2 and HCl can be used to predict if an eruption is about to occur.
- **Satellites**: Measure the height of the volcano and can detect any changes in its shape.
- **Hazard mapping**: Past eruptions can be analysed and the different volcanic hazards identified. These can then be used to create maps that **show the areas at risk from the different hazards**. These maps can be used to determine safe zones for people to evacuate to in an eruption and also help emergency services.

Protection, control and reduction

- **Building improvements for earthquakes**: Rubber shock absorbers in foundations, steel frames which can sway, open areas where people can assemble, in developing countries wire mesh retrofitting can be used to stop falling debris, lightweight roofs and safety glass can all be used to minimise the loss of life and damage to buildings during an earthquake.
- **Protection against volcanoes**: Using the hazard maps exclusion zones can be created. The environment around a volcano can also be adapted and altered to protect the local people and their infrastructure. Channels can be created that **divert lava flow,** this is an example of soft engineering. Making sure buildings are not in valleys or downstream from the path of the lava flow is the best way to ensure no damage is done. Having a **roof which is strong and at a steep angle** ensures that any ash that has fallen will not cause the roof to collapse.
- **Preparation:** Hospitals, emergency services and residents all need to practise and carry out drills if they are in a high risk area. Buildings in high risk areas should all have emergency kits.

Rescue and recovery

- **Short-term**: Search and rescue teams that use **sniffer dogs and/or thermal imaging cameras** are especially useful after earthquakes when people will be trapped under buildings as most people only have 72 hours when trapped under a building. **Medical aid, food and drinking water** all need to be supplied. Large scale operations work best with lots of people helping as this ensures that all survivors can be found. In developing countries rescue efforts usually come from NGOs and emergency disaster teams from other countries.

- **Long-term**: Infrastructure and amenities need to be built and improved on after the disaster so that they are less likely to be damaged if the hazard were to occur again. Compensation is given out through **insurance** although this is often insufficient. Some governments try to **stimulate the economy** again for example cash payments were given to people after the 2011 Christchurch earthquake so that they could buy necessities. This in turn helped to stimulate the local economy. Long-term recovery is very **difficult in LICs** because after the initial hazards are over many of the **aid inflows stop** making it hard for rebuilding and recovering to continue.