Edexcel Geography GCSE

Tectonics

Hazardous Earth

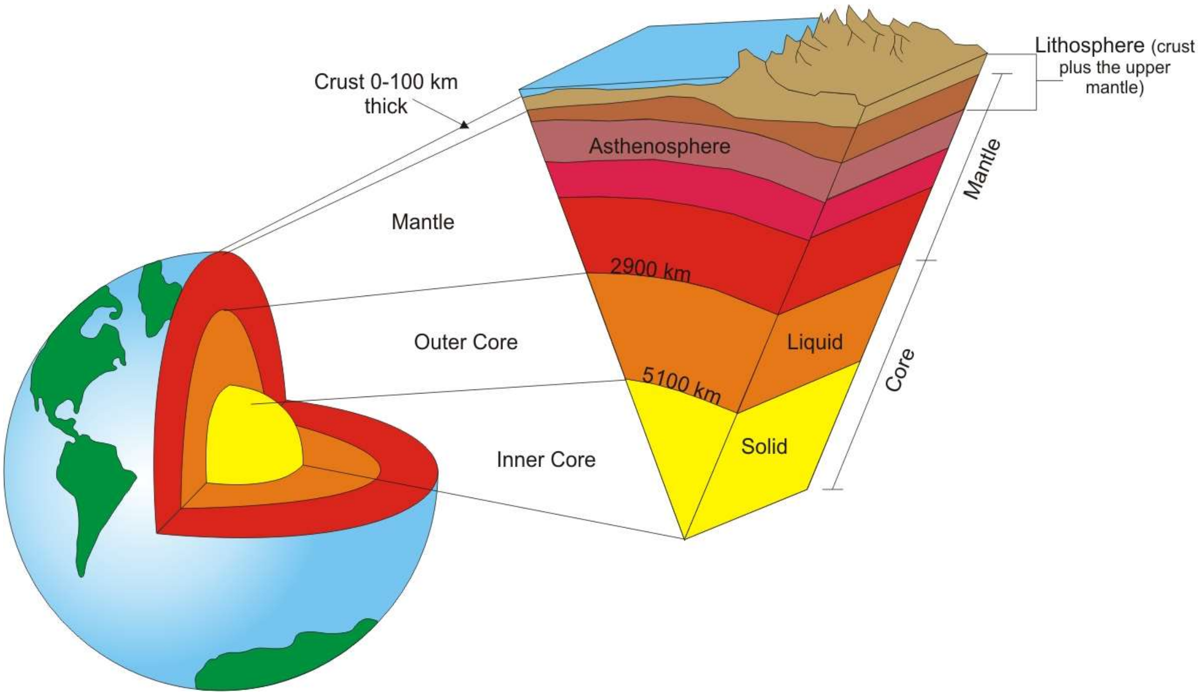
Detailed Notes

The Structure of the Earth

As we cannot physically see inside the Earth, scientists who study the Earth (geologists) have used different methods to **predict its structure**. The Earth is separated into **layers** of different depths and compositions.

Starting from the **centre**, the Earth's structure is thought to be separated into these layers:

- **The inner core**
- **The outer core**
- **The lower mantle**
- **The upper mantle (the asthenosphere)**
- **The lithosphere**
- **The crust (the top of the lithosphere)**



(Source:https://www.leeds.ac.uk/ruskinrocks/Earth%20Structure.html)

The deepest artificial point on Earth is the **Kola Superdeep Borehole** in the Pechengsky District, Russia. Geologists drilled **40,230ft-deep (12.2km)** down into the continental crust, which is only around **one third** of the way through the crust.

(Source: Janko Azkoyen/ Atlas Obscura)

The Earth's layers have different **properties** and **compositions**, outlined on the next page.

Inner Core

- The inner core is a solid ball of iron/nickel.
- It is under **a huge amount of pressure** as it has the weight of the whole Earth pushing against it, which causes it to remain solid.
- Within the inner core, **radioactive elements** like uranium and thorium are **decaying**. Radioactive decay gives off lots of heat (the inner core is over 5000°C!). This heat is responsible for **Earth's internal energy**, and it spreads throughout the different layers.

Outer Core

- The outer core is a **molten (liquid) layer** of iron and nickel that surrounds the inner core.
- The heat from the inner core creates **convection currents** (see convection currents diagram on the next page) in the outer core, which transfers heat to the **mantle** above.

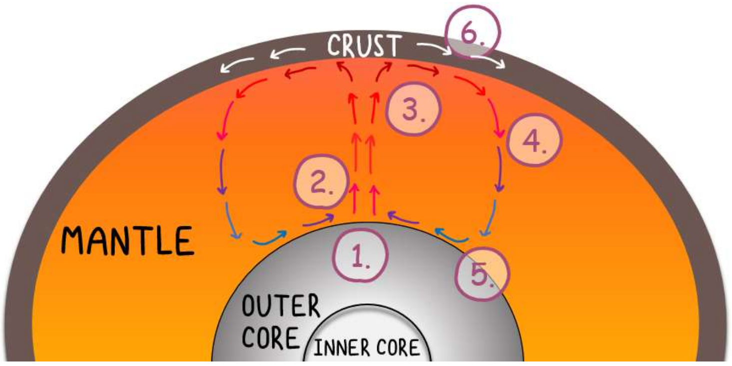
Mantle

- The mantle is the largest layer of the Earth. It is mainly solid rock apart from at the **very top**, where it behaves like a very dense **fluid** (like silly putty).
- The top layer of the mantle is known as the **asthenosphere**.
- The asthenosphere constantly moves and flows due to **convection currents**, which moves the **solid lithosphere above**.

Lithosphere

- The lithosphere is **solid rock** that lies on top of the asthenosphere.
- The majority of the lithosphere is technically in the mantle, but the very top of the lithosphere is the Earth's crust.
- The crust is split up into multiple large **slabs** called **tectonic plates**. These plates range from **tens to hundreds of kilometres thick**.
- The crust is either **continental crust** which makes up our land (old, less dense and thick) or **oceanic crust** which makes up the ocean floor (younger - but still very old! - dense and thin).
- Plates move due to the **movement of the liquid asthenosphere.** This process can be seen in the convection currents diagram on the next page.

Convection Currents



This is a simplification. Convection currents only occur within the upper mantle (asthenosphere) where it is semi-molten.

1. Energy from radioactive decay in the **core** heats up the fluid asthenosphere
2. The hot liquid is **less dense** than its surroundings, so it **rises upwards**
3. When it reaches the top, it **cools**
4. It becomes **more dense**, and therefore **sinks** back down to the bottom
5. It is **heated up again**, and the cycle continues
6. The **plates**, which lie on top, are **pushed** and **pulled** by the convection currents in the asthenosphere

The Properties of Earth's Layers: Summary Table

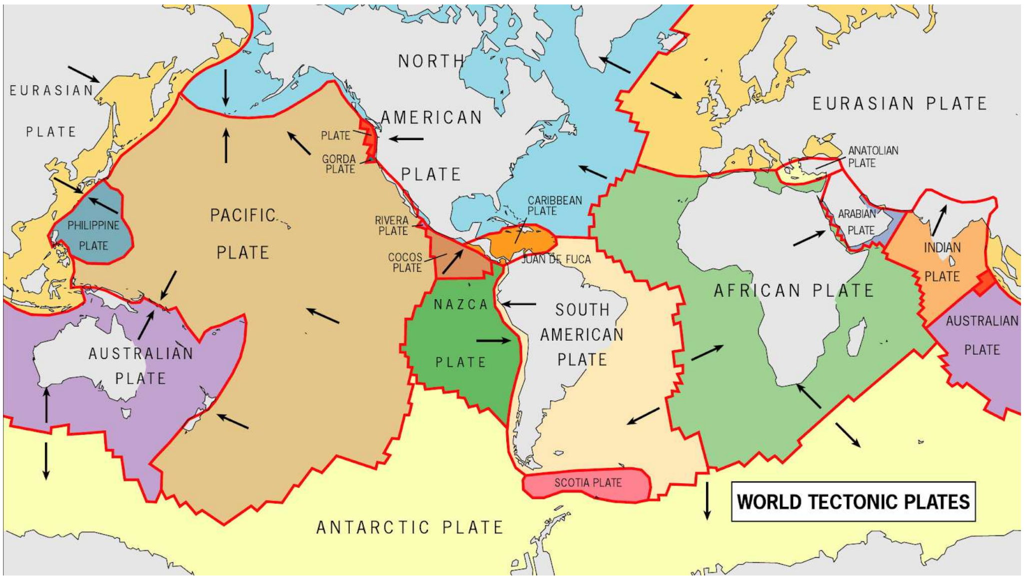
Increasing depth

Layer		Depth	Physical State	Density (g/cm^3)	Composition	Temp (°C)
Lithosphere	Continental Crust	0-100km thick (usually 30-50km thick)	Solid	2.7	Rocks similar composition to granite	Air temp - 900°C
	Oceanic Crust	Usually 6-8km thick	Solid	3.3	Rocks similar to basalt	Air temp - 900°C
Mantle	Asthenosphere	Starts anywhere from 35-250km - 700km	Partially molten/ fluid	3.4 - 4.4	Silicates (made of silicon)	900 - 1600°C
	Lower Mantle	700 - 2900km	Solid	4.4 - 5.6	Silicates (made of silicon)	1600 - 4000°C
Core	Outer Core	2900km - 5270km	Liquid	9.9 - 12.2	Iron and nickel	4000-5000°C
	Inner Core	5270km - 6370km	Solid	12.6 - 13.0	Iron and nickel	Around 5400°C

Plate Tectonic Movement

Tectonic plates **move** very slowly **in relation to each other** and in different directions. They move next to each other, towards each other, away from each other, and sometimes they can be pushed over and under one another.

The **global distribution** of plates can be seen below. Where the plates **meet** - indicated in red - is known as a plate **boundary**. The arrows indicate the direction that the plates are moving.



The global distribution of plates. (Source: www.jkgeography.com/plate-tectonics)

Thinking Further: The Theory of Continental Drift

Plate tectonic movement has been happening for **hundreds of millions** (if not billions) of years! The continents today were not always where they are now, in fact it is theorised that there was once a huge **supercontinent** called **Pangaea** that split off to form today's continents.

This theory has been debated for hundreds of years, but new evidence such as **fossil records** have made it possible to **reconstruct the past movements of the continents**.

The continents we see today are not **still**! Plate tectonic movement happens all the time.

For example, the Atlantic Ocean is growing, and we are moving away from the USA about 2-5cm a year!

(Image source: pubs.usgs.gov/gip/dynamic/historical)

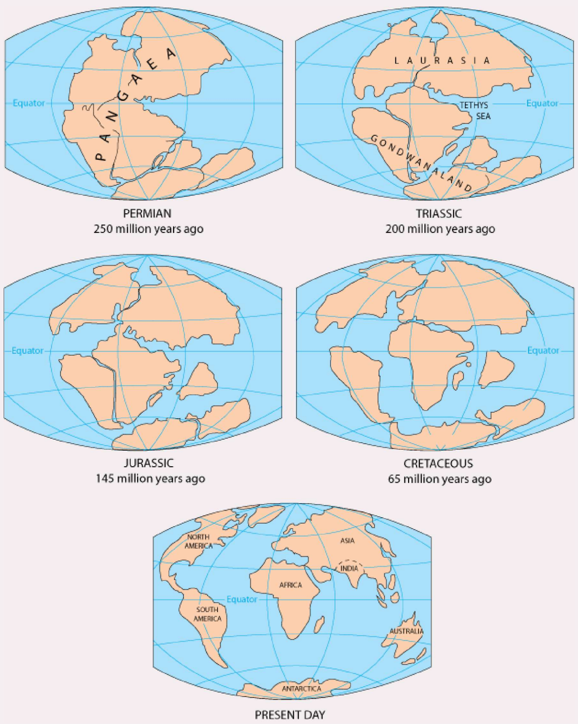


Plate Boundary Processes

Plate boundaries interact in different ways depending on the **direction they are moving** in relation to each other. This controls the types of **landforms** that are created at boundaries, as well as the type of **tectonic hazard** generated. There are **3 types** of plate boundary:

Divergent: Plates move **away** from each other

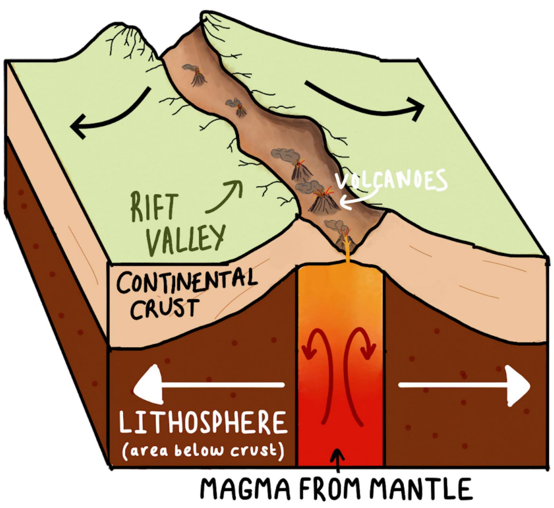
Convergent: Plates move **towards** each other

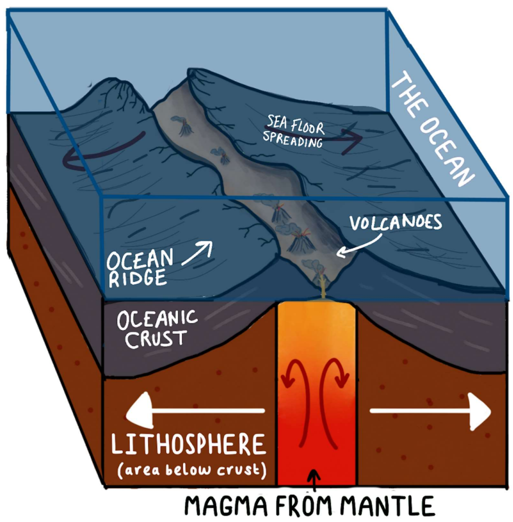
Conservative: Plates move **alongside** each other

Different **physical processes** take place at each type of plate boundary that cause volcanic and earthquake activity.

Divergent Plate Boundaries

- At a **divergent** plate boundary, the plates are moving **away** from each other.
- When the two plates are **pulled apart**, magma rises in between the **gap left by the two plates separating**. Lava (when **magma is above ground**, it is classed as lava) then pours out onto the surface.
- **Volcanoes** form in the areas where **lava pours out**. This lava is usually runny and free-flowing, which creates **flatter volcanoes**. Earthquakes also occur here as the plates shake and vibrate when they move apart.
- This process can happen on **continental** crust (left) or **oceanic** crust (right).



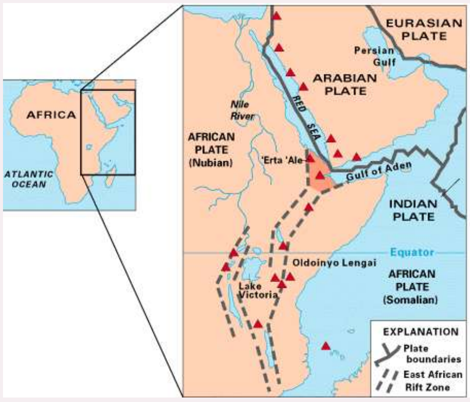


- When new land is formed on the ocean floor, this is known as **sea floor spreading** (as the floor spreads and gets wider).
- When lava cools, it forms **rock**. Over time, this rock builds up and can form **islands**, for example Iceland is a volcanic island. Iceland sits on the **Mid-Atlantic ridge**, which is where the lava pours out from.

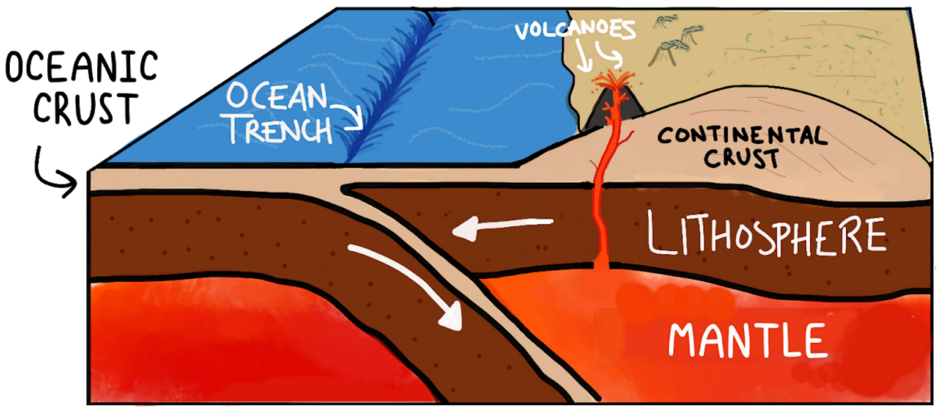
Thinking Further: Rift Valleys

On **continental crust**, a divergent plate boundary causes huge fractures in the land, creating a lowland region known as a **rift valley**.

A famous example of a rift valley is the **East African Rift Valley.** The rift zone stretches for **thousands of kilometres** down East Africa, and many **volcanoes** have historically been present in this area (shown by the red triangles in the map to the right). If the divergent plate boundary continues on its path, the East of Africa may eventually **split off** from the rest of mainland Africa, and will be **separated by sea**.



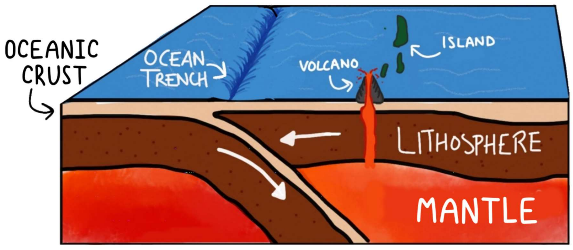
- At a **convergent** plate boundary, the plates move **towards** each other.
- This causes one of the plates to **subduct** (sink) below the other into the mantle, where it is destroyed.
- In the diagram below, **oceanic** crust is moving towards **continental** crust. This is happening off the **west coast of South America** where the **Nazca Plate** is subducting below the **South American Plate**.



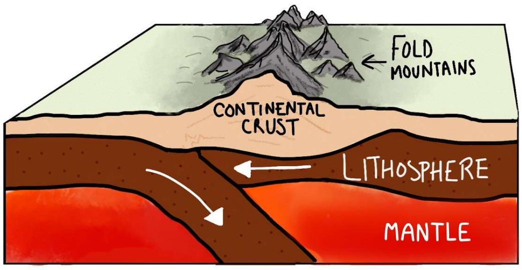
Convergent plate boundaries cause earthquakes and volcanoes due to the following processes:

1. The denser oceanic crust is **subducted** below the continental crust
2. The plate that is subducting leaves a deep **ocean trench**
3. **Friction** between the two plates causes **strong, deep earthquakes**
4. The oceanic crust is melted as it is pulled deeper into the mantle, creating **magma**.
5. This magma causes **pressure to build up** under the crust.
6. Eventually the magma pushes out through weaknesses in the crust, creating **explosive volcanoes**.

This process can also happen between two oceanic crust plates, where the denser plate sinks below and islands **in the ocean** can form. For example, the Mariana trench.

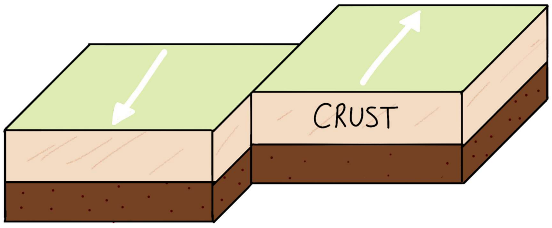


When two **continental plates meet**, neither plate can subduct below the other. The crust is instead crumpled upwards by the pressure building between two plates, creating **fold mountains**. An example of this is the Himalayas, which formed due to the Indian Plate and Eurasian Plate colliding.



Conservative Plate Boundaries

- At a conservative plate boundary, **parallel plates** move in **different directions** or at **different speeds** in relation to each other.
- When these plates move side by side, **friction** builds between the plates.
- The friction **builds up** over many years, and eventually the pressure becomes so large that the plates eventually move in a **sudden jolt**.



- This releases a lot of **energy** which sends **vibrations** through the ground. This is an **earthquake**.
- On oceanic crust, this movement can displace a lot of water, which causes large waves called **tsunamis**.
- On continental crust, **fault lines** can occur where the ground is cracked by the movement.
- There are **no volcanoes** on conservative plate boundaries because **no magma** is being generated.

Hotspots

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).

Volcanic Hazards

Volcanoes on Divergent Plate Boundaries

Volcanic eruptions on **divergent plate boundaries** are characterised by **non-explosive** eruptions with **runny, fast flowing lava**. The lava is made up of **basalt**, which is very hot and has a low **viscosity** (thickness).

This creates **shallow sided** (flat) **shield volcanoes**.

(Source: Rax / Ragnar Axelsson)

Volcanoes on Convergent Plate Boundaries

Volcanic eruptions on **convergent plate boundaries** are usually **explosive** due to the **high pressure** the magma is under, meaning hot gas, ash and rock is spewed from the volcano. Fast, extremely hot clouds of gas, ash and debris can roll down the side of the volcano in a **pyroclastic flow**, which can incinerate anything in its path.

The lava is made out of **andesite**, causing the lava to be **viscous** and very slow flowing. Steep sided **composite volcanoes** are formed from these eruptions.

(Source: https://edition.cnn.com)

Volcanoes on Hotspots

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(Source: https://www.youtube.com/watch?v=i-3IrJYq2Ko)

Earthquake Hazards

Earthquakes on Conservative Boundaries

Earthquakes on conservative boundaries can be **very destructive** and **intense**. If an earthquake is **shallow** (which means it happens **close to the surface**), the earthquake can cause **very intense shaking**, which can bring down buildings, break pipes and destroy infrastructure.

(Source: The Chronicle 1906)

The San Andreas fault is a **conservative plate boundary** that runs through California. In 1906, there was a 7.9 magnitude earthquake on this boundary, creating devastation in San Francisco. This can be seen in the image to the right.

Earthquakes on Convergent Boundaries

When one plate **subducts** below the other, friction can cause it to become stuck and pressure can build. When the plates eventually shift suddenly, the pressure is released as a **very strong earthquake**. These earthquakes can be very severe, especially if they are **shallow** (although they are usually deep as the plate is sinking).

(Source: storymaps.arcgis.com/stories)

In 2011, there was a very severe earthquake in Japan caused by a convergent boundary. It measured 9.0 on the Richter Scale and triggered a huge **tsunami** after!

Earthquakes on Divergent Boundaries

Divergent boundary earthquakes do occur, but they are usually **smaller** and **cause less damage**. Earthquakes are usually less severe as there is less built up pressure at these boundaries.

The Richter Scale

The Richter Scale is the scale that **seismologists** (people who study earthquakes) use to measure the **strength** of an earthquake.

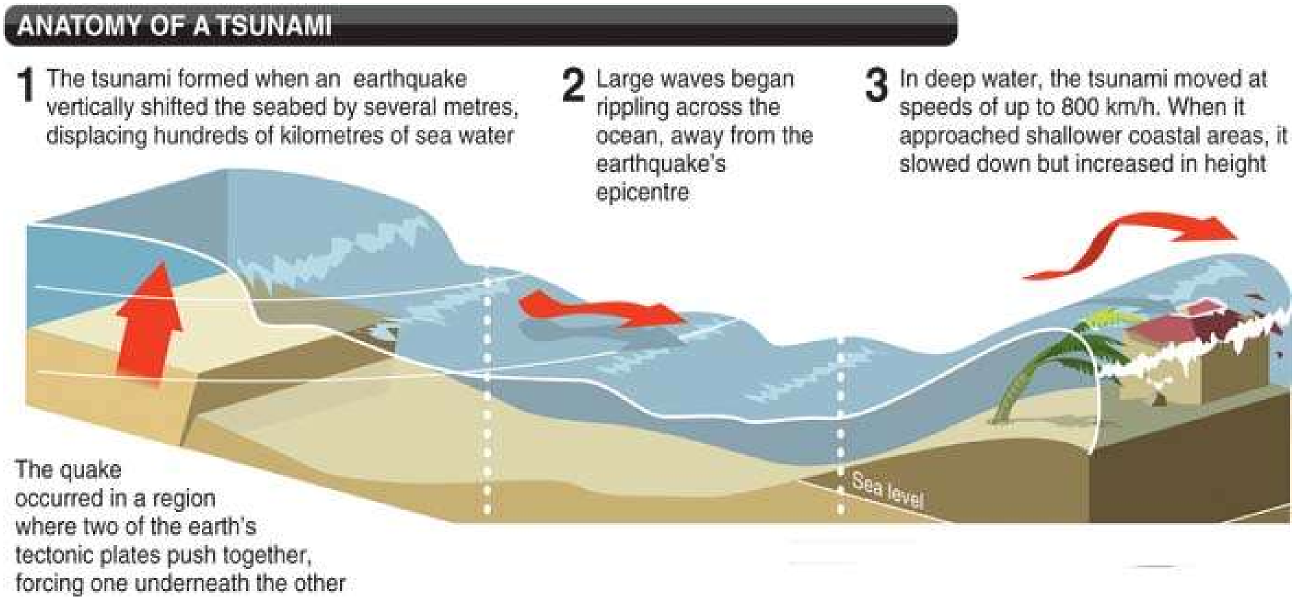
The scale is **logarithmic**, which means each number is **10x bigger** than the last, so a **5.0 magnitude earthquake would be 10x bigger than a 4.0 magnitude earthquake**.

Tsunamis

Earthquakes can trigger **huge waves of seawater** to travel across the ocean and **hit a coastal area**. This large wave is known as a **tsunami**, and can cause extreme flooding and damage to property.

Formation:

- When an oceanic crust is jolted during an earthquake, all of the water above this plate is **displaced**.
- 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.



(Source: ABC / Reuters)

Hazards Formed on Plate Boundaries: Summary Table

Boundary	Volcanoes	Earthquakes
Divergent	Not explosive eruptions. Runny, fast flowing, **basaltic** lava. Volcanoes are usually shallow sided.	**Smaller earthquakes** as there is less built up friction (5.0-6.0 on the Richter Scale).
Convergent	Very explosive eruptions. Thick, slow moving **andesitic** lava. Usually steep sided volcanoes.	Earthquakes are **very strong** (up to 9.5+ magnitude). They may be deep, which makes them weaker.
Conservative	No volcanoes as no crust is being destroyed and no magma is generated.	**Very strong** earthquakes. They can be shallow, meaning they will cause more damage (up to 8.5 magnitude)