AQA Geography GCSE

3.1.1.2: Tectonic Hazards

Detailed Notes

Plate Tectonic Theory

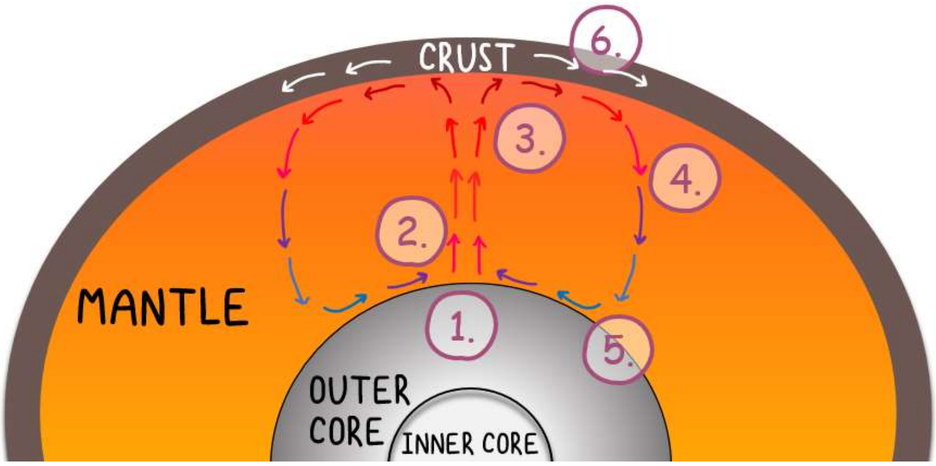
What Is A Tectonic Hazard?

The word **tectonic** refers to the structure of the **Earth's crust**, the outside layer of the Earth. The crust is broken up into **huge slabs of rock** called **tectonic plates**. The **physical processes** that these tectonic plates undergo cause movements within the Earth, which - in turn - create earthquakes and volcanic eruptions. These hazards are therefore referred to as **tectonic hazards.**

Tectonic Plates

As previously mentioned, the Earth's crust is split up into multiple large **slabs** called **tectonic plates**. These plates range from **tens to hundreds of kilometres thick**, and are either classed as **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).

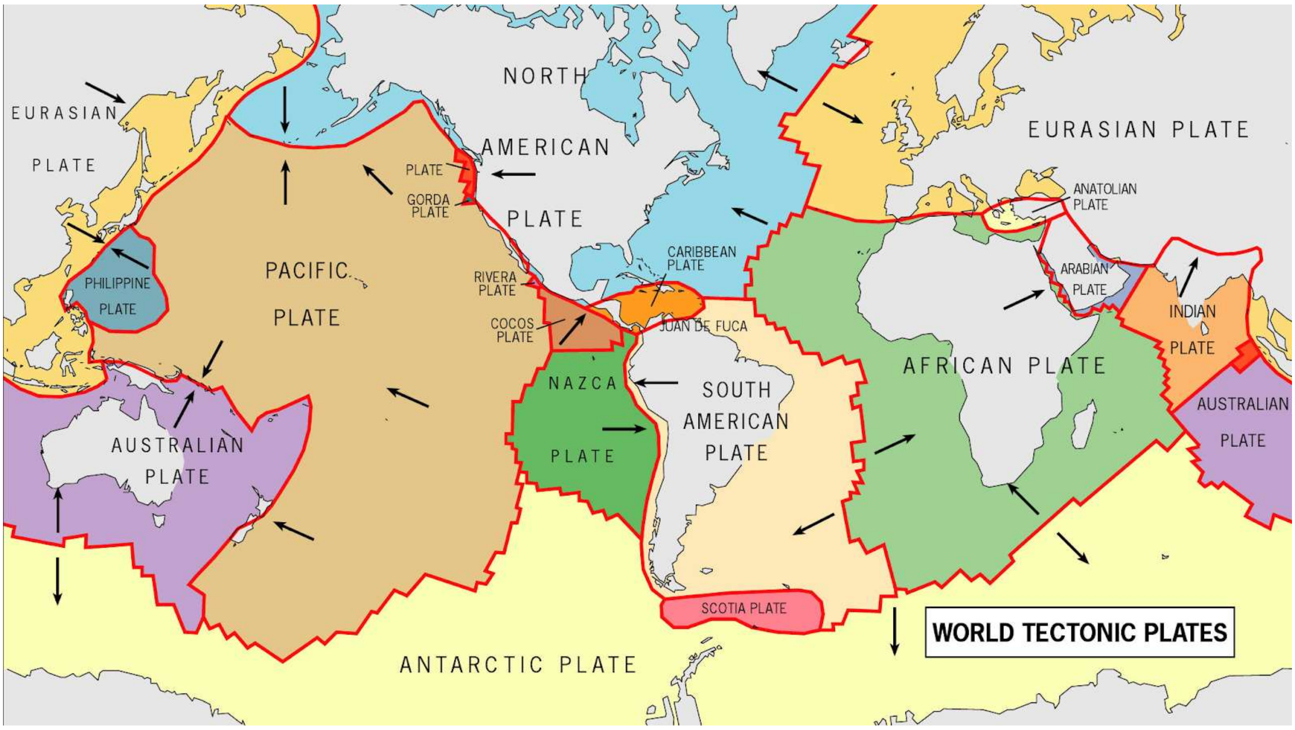
Plates move due to the **movement of the liquid magma** deep within the Earth. The movement of magma creates **convection currents**, which are **flows of heat**. Below is a diagram of how convection currents work inside the Earth:



1. The **core** heats up the magma in the mantle
2. The hot magma 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 magma

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 **margin**. 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

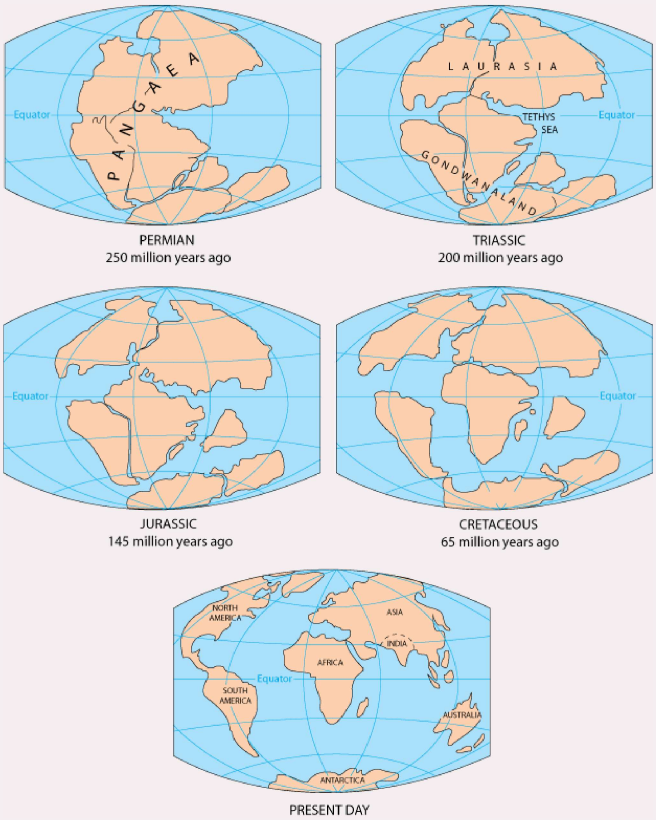
Plate tectonic movement has been happening for **hundreds of millions** (if not billions) of years! The continents today were not always where they are now, in fact it is theorised that there was once a huge **supercontinent** called **Pangaea** that split off to form today's continents.

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.

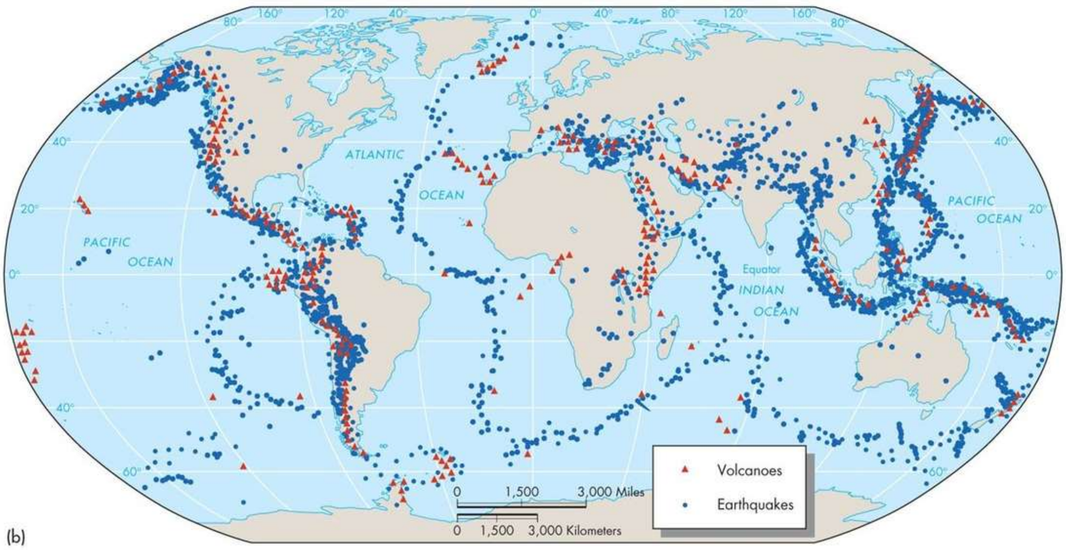
For example, the Atlantic Ocean is growing, and we are moving away from the USA about 2-5cm a year!

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



The Global Distribution of Tectonic Hazards

In general, **tectonic hazards** (earthquakes and volcanic eruptions) occur **on plate margins**. There is a clear pattern of volcano and earthquake distribution along plate margins, such as along the west of North America and South America, or in the Atlantic Ocean between Africa and South America.



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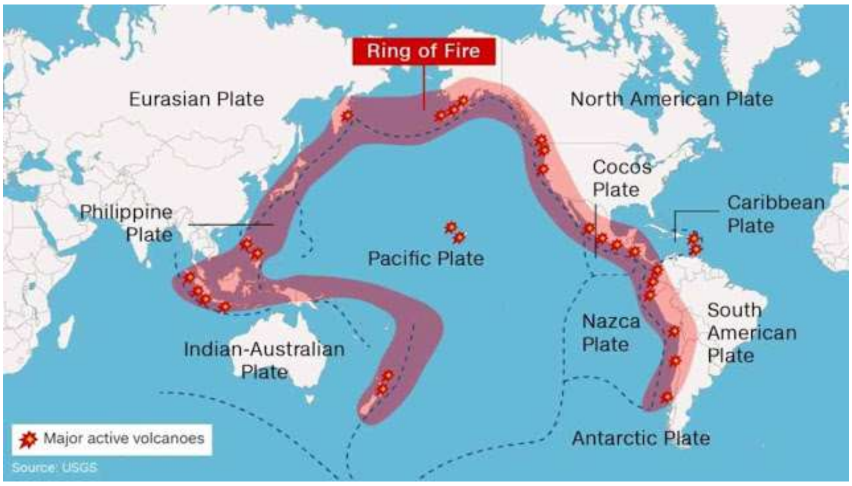
An example of an area with high volcanic and earthquake activity is The **Ring of Fire**, which is located in the Pacific Ocean (seen in the map to the right).

The earthquakes and volcanoes **follow the margins** between the **Pacific tectonic plate** and other plates.



If you compare these **tectonic hazard maps** to the map of **plate margins** above, you can clearly see a **pattern between the margins and tectonic hazards**.

Earthquakes occur along **plate margins** due to plate movements causing **vibrations**. **Volcanoes** occur along certain plate margins as **magma** (molten rock found underground) feeds volcanoes, and this **magma can get to the surface** at certain plate margins.

Volcanoes do not **always** occur on plate margins (like in the **middle of the Pacific Plate** shown in the map above). This is where the **magma breaks through the middle of the plate** and travels up to the surface, which is known as a **hotspot**. The hotspot shown in that map is Hawaii!

Plate Margin Processes

Plate margins 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 margins, as well as the type of **tectonic hazard** generated. There are **3 types** of plate margin:

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

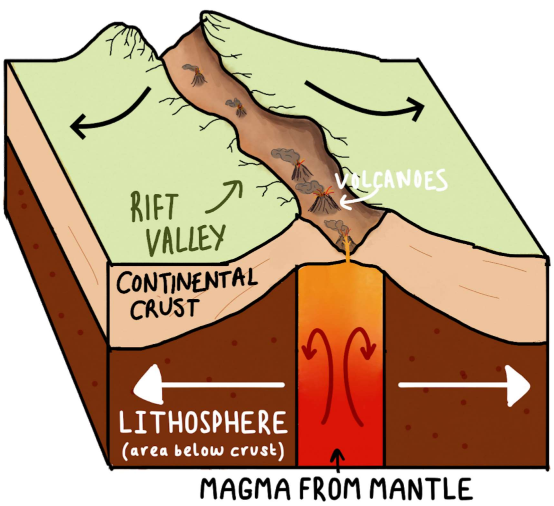
Destructive: Plates move **towards** each other

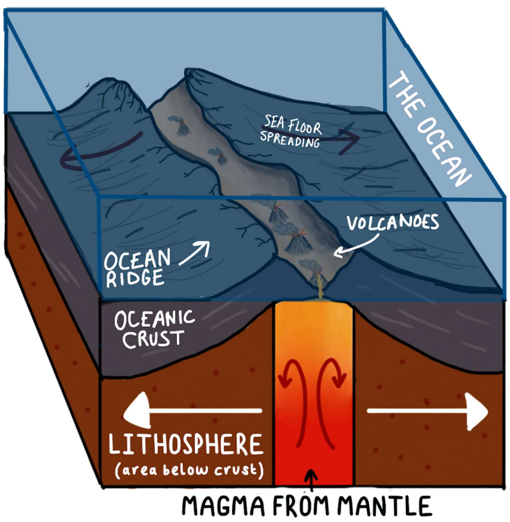
Conservative: Plates move **alongside** each other

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

Constructive Plate Margins

- At a **constructive** plate margin, 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).



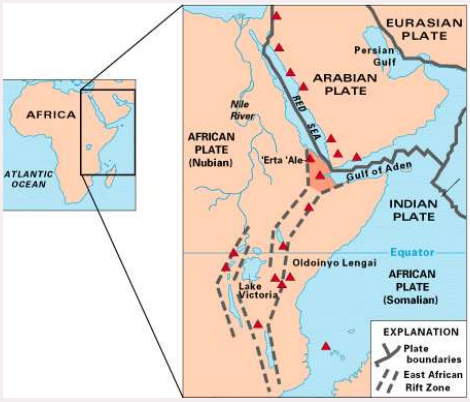


- When new land is formed on the ocean floor, this is known as **sea floor spreading** (as the floor spreads and gets wider).
- When lava cools, it forms **rock**. Over time, this rock builds up and can form **islands**, for example Iceland is a volcanic island. Iceland sits on the **Mid-Atlantic ridge**,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

Thinking Further: Rift Valleys

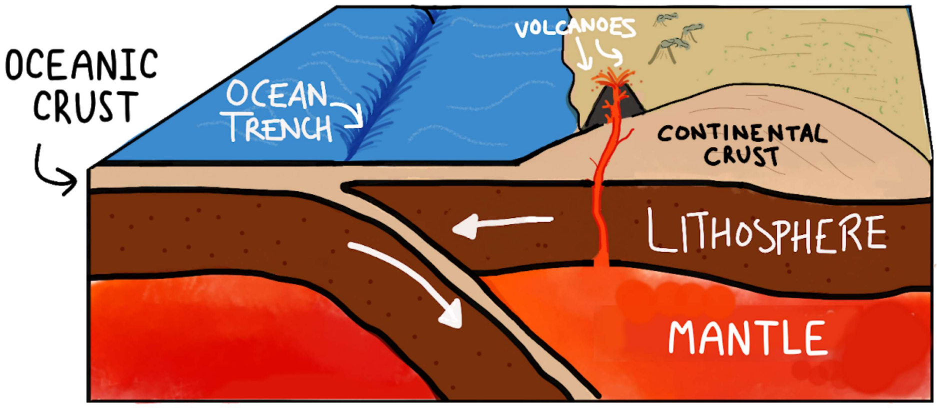
On **continental crust**, a constructive plate margin causes huge fractures in the land, creating a lowland region known as a **rift valley**.

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 constructive plate margin continues on its path, the East of Africa may eventually **split off** from the rest of mainland Africa, and will be **separated by sea**.



Destructive Plate Margins

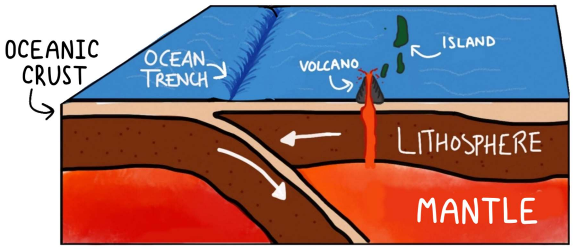
- At a **destructive** plate margin, the plates move **towards** each other.
- This causes one of the plates to **subduct** (sink) below the other into the mantle, where it is destroyed.
- In the diagram below, **oceanic** crust is moving towards **continental** crust. This is happening off the **west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



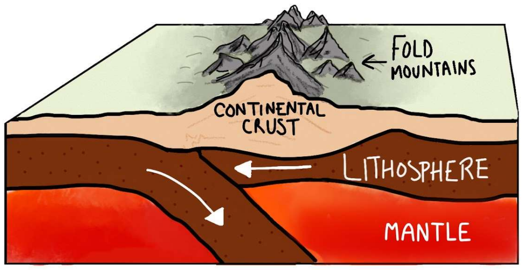
Destructive plate margins cause earthquakes and volcanoes due to the following processes:

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.

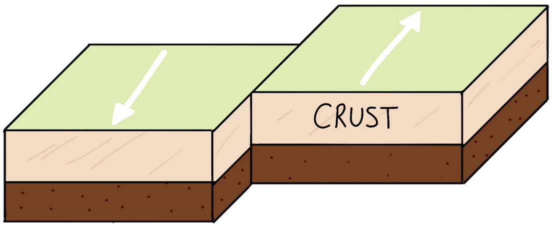


When two **continental plates meet**, neither plate can subduct below the other. The crust is instead crumpled upwards by the pressure building between two plates, creating **fold mountains**. An example of this is the Himalayas, which formed due to the Indian Plate and Eurasian Plate colliding.



Conservative Plate Margins

- At a conservative plate margin, **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**.



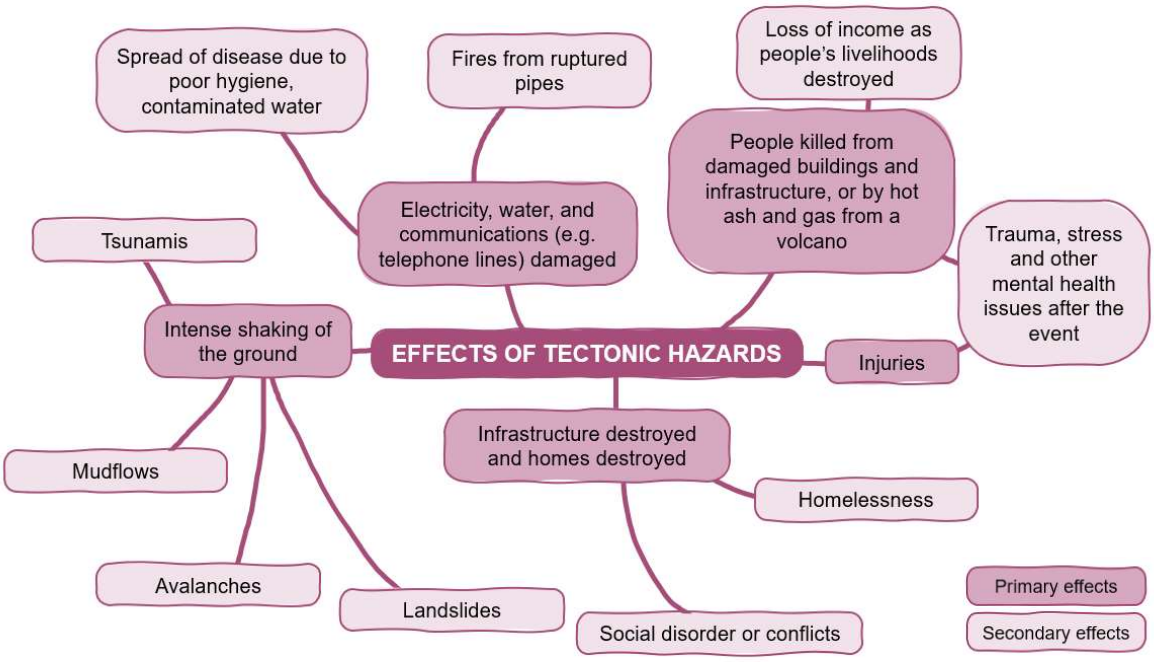
- This releases a lot of **energy** which sends **vibrations** through the ground. This is an **earthquake**.
- On oceanic crust, this movement can displace a lot of water, which causes large waves called **tsunamis**.
- On continental crust, **fault lines** can occur where the ground is cracked by the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

The Effects of Tectonic Hazards

Tectonic hazards can have devastating effects **socially, economically** and **environmentally**. The effects of any hazard can be divided into **primary effects** and **secondary effects**.

Primary effects: The effects that are **directly caused by the natural hazard** itself. For example, people being **killed** or **injured** when an earthquake causes **buildings to fall down**, or lava and ash damaging infrastructure.

Secondary effects: The effects that are a **result of the primary effects**. For example, **homelessness** due to homes being destroyed, or a **tsunami** or **landslide** caused by the **original earthquake**.

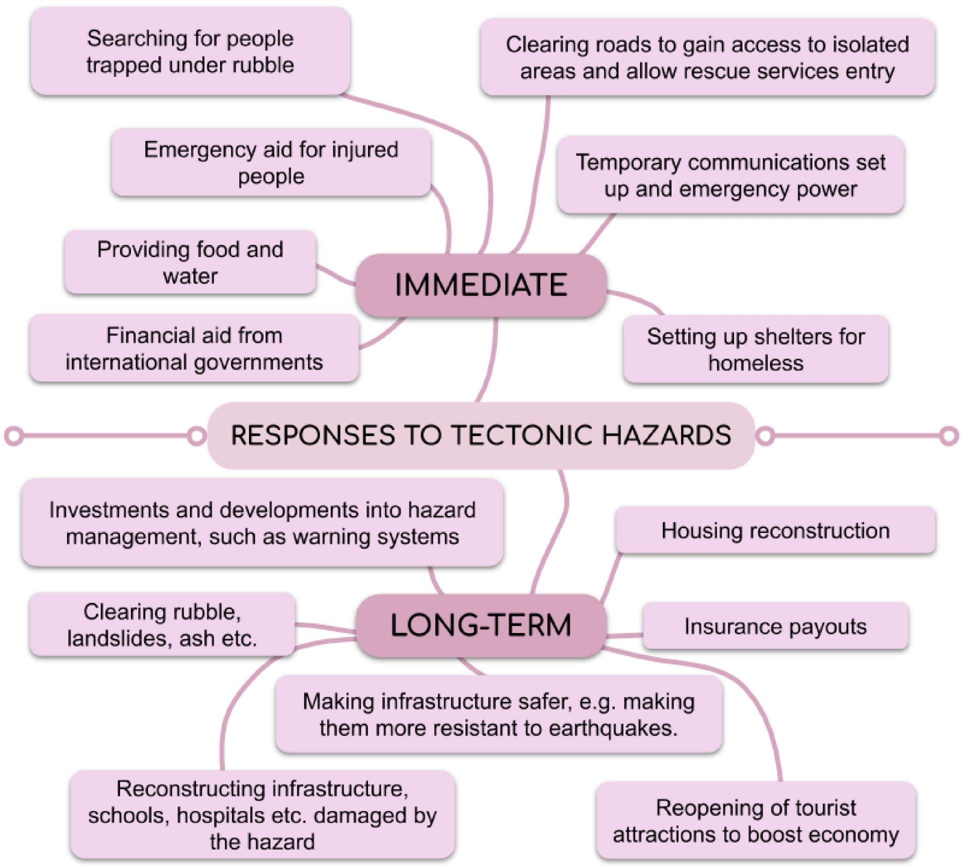


The Responses to Tectonic Hazards

The term **'responses'** refers to how the **local community**, the **government**, and **international organisations/governments react** to a hazard so that the **effects** can be reduced as much as possible. Responses are either classed as **immediate** or **long-term**.

Immediate responses: Actions taken **as soon as the hazard happens** and in its immediate **aftermath** (hours, days, and potentially a week or so after the event). Immediate responses usually aim to **reduce loss of life** and provide **vital aid and resources**. For example: **search and rescue, medical care, food and water, shelters** for those who have lost their homes.

Long-term responses: Actions taken **after** the immediate responses when the effects of the hazard have been minimised (weeks, months, and years after the event). Long-term responses aim to **restore normality** and **reduce risk** in the **future**. For example: **rebuilding** infrastructure and homes, **cleaning up** the effects of the hazard, building **defence** mechanisms, setting up **warning systems**.



Why Do People Live In Hazardous Places?

Many people **choose to live in hazardous places** despite the very real **risk** that exists when living in these areas. In 2015, it was reported that **2.7 billion people** live in **seismically active areas** (areas near moving plate margins that experience frequent and intense earthquakes) and more than **400 million people** live near one of the 220 most **dangerous volcanoes.**

So why do so many people still choose to live in these areas even though it is dangerous - and potentially life threatening - to do so? There are many reasons: it may be economically beneficial, the risk may seem small in comparison to the advantages, or some may not be able to afford to move. Some of these reasons are discussed below.

1. The Benefits That Tectonic Hazards Bring

There may be many negative effects of tectonic hazards, but they also bring positives.

When volcanoes **erupt**, they emit lots of **ash** and **material** into the air, which eventually settles on the surrounding slopes and its **base**.
There are lots of **nutrients** within volcanic material, so when ash and debris falls onto the land these nutrients find their way into soils and make the soils **fertile**. Agriculture is therefore a **major source of income** for people living in these areas, and many people will choose to live here as they can make money from growing and selling crops. Volcanic soils are some of the **most fertile in the world**.

The picture to the right is an image of **Mayon Volcano** in the Philippines. Despite it being an **active volcano** that frequently erupts, many people live in the areas surrounding this volcano due to the **fertile soils**.

(Source: www.straitstimes.com)

Hazardous areas can also have a **well developed tourism industry**, which means many **choose to live in hazardous areas** for **work**. **Volcanic areas** such as Iceland can attract a large number of tourists; Many come to see the famous volcano Eyjafjallajökull, or visit the **hot springs** which are heated by **geothermal activity** underground, so a lot of people rely on the tectonic activity for an income.

2. Hazards are Monitored and Managed

There have been **major advances** in **monitoring technology** for tectonic hazards, which have enabled **warning systems** to be developed. For example, warning signs of an **impending eruption** (e.g. bulging, seismic activity, steam) can be monitored and people can be told to **evacuate** if there is an eruption coming. Large earthquakes in the ocean can also be monitored to tell people when there will be a tsunami. Many people will therefore live in hazardous areas as they know the risk will be reduced by these **warning systems**.

There have also been developments such as **better building design** which lessen the effects of hazards, meaning people are less at risk while living in these hazardous areas. For example, in Japan - which frequently has earthquakes - many buildings are **built to withstand very severe shaking**. One of these buildings is pictured on the right, which has a **carbon fibre 'curtain'** to minimise the effects of shaking.

(Source:architizer.com)

3. Infrequency of Tectonic Events

Some of the **largest cities** are near tectonic margins, such as Osaka in Japan, San Francisco in the USA, Manila in the Philippines. Many people decide it is **not worth giving up their area's lifestyle and culture** when tectonic hazards appear so **infrequently**.

For example, the last time there was a **major earthquake** on the San Andreas Fault in California was **1857**, so for many people the risk of an earthquake is not even considered. For some, it is not worth **giving up their life and the positives that come with their area** because of the tectonic risk there, especially if the tectonic hazard may not even happen in their **lifetime**.

This is **Mount Vesuvius** in Italy, which overlooks many different towns. Even though Vesuvius is an active volcano, and potentially very dangerous (this is the volcano that destroyed Pompeii!), people still live here because it has not erupted since 1944 so people do not see it as a **high risk**.
(Source: heromanguy.com/italy-travel-blog/can-it-erupt-again-mount-vesuvius-facts-and-history/)

4. Poverty and Education

Some people do not have a **choice** in whether or not they live in a **hazardous area**, as they may not be able to **afford to move away**.

Especially in **less wealthy countries**, the top priority for many households is having an **income**, **food**, and **necessities**. For these people, the risk of a hazard is a **less pressing issue**.

Also, in some countries there is a lack of **education** about the tectonic hazards that pose a risk to the population. Some may not be aware that there is any **risk** of living in the area, and therefore are not concerned.

Hazard Management

In order to **reduce the effects** of a tectonic hazard, strategies to **manage hazards** have been developed. These management strategies **prepare** a population for a hazard so that when it does occur, there are fewer **effects**. There are four ways to manage hazards:

- **Monitoring:** detecting and recording **physical changes** and **warning signs**
- **Predicting:** using **monitoring** as well as **historical trends** and **computer based modelling** to predict when a tectonic event may occur.
- **Protecting:** Increasing the **resistance of a population** to tectonic hazards by **physically designing** things that will **withstand tectonic hazards**
- **Planning:** Having **systems** in place, such as evacuation routes, so that if an event does occur, the population is prepared in advance.

Monitoring

Volcanologists and seismologists monitor **changes** in the area surrounding fault lines and volcanoes to see how far away a **hazardous event** may be.

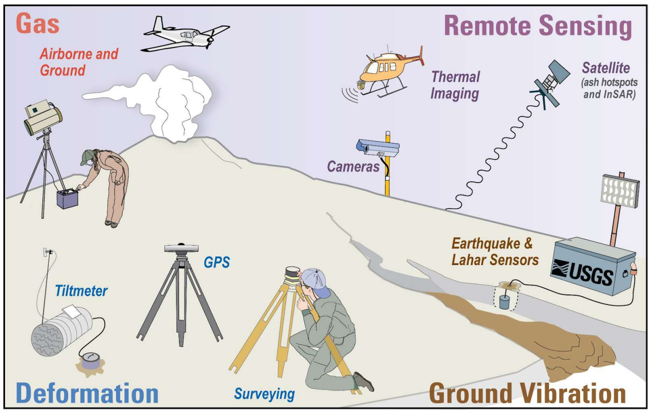
Earthquakes are **difficult to monitor** as earthquakes usually do not display any **warning signs. Seismologists** (people who study earthquakes) do monitor **small tremors** in the ground as well as **ground deformation** and changes in **groundwater**, but as of now there is no technology that can indicate with certainty that an **earthquake** is coming.

There are **many changes** in a **volcano** that volcanologists monitor to gain an idea of how far away an **eruption** could be. For example:

- **Ground deformation**: bulges in the ground can indicate the movement of magma
- **Gases:** certain gases indicate rising magma, such as sulfurous gases
- **Changes in heat**: temperature differences also indicate processes beneath the surface
- **Vibrations underground**: small earthquakes can indicate changes underground
- **Smaller eruptions of smoke and steam**: indication of a larger eruption coming

Different equipment such as **satellites** and **sensors** are used to monitor changes in volcanoes.

(Source: volcanoes.usgs.gov/vhp/monitoring)



Predicting

It is possible to **make predictions** of when a hazardous event may occur. As mentioned above, **volcanic eruptions** can be predicted from monitoring **warning signs**. **However on a larger time scale**, **historical trends** in tectonic events can give some indication of the time frame of when another similar event may occur, or even if an event is **overdue**.

As earthquakes are caused by a **buildup of energy** due to friction between **two plates**, if an earthquake hasn't happened for a while, scientists predict the next earthquake will be **bigger** because energy has been **building up for longer**. It has been over 200 years since there was a major earthquake on the San Andreas Fault, meaning some scientists predict there will be a **high magnitude earthquake**, which is sometimes referred to as 'The Big One'.

Scientists can also **model the data** on computers to more accurately predict hazardous events.

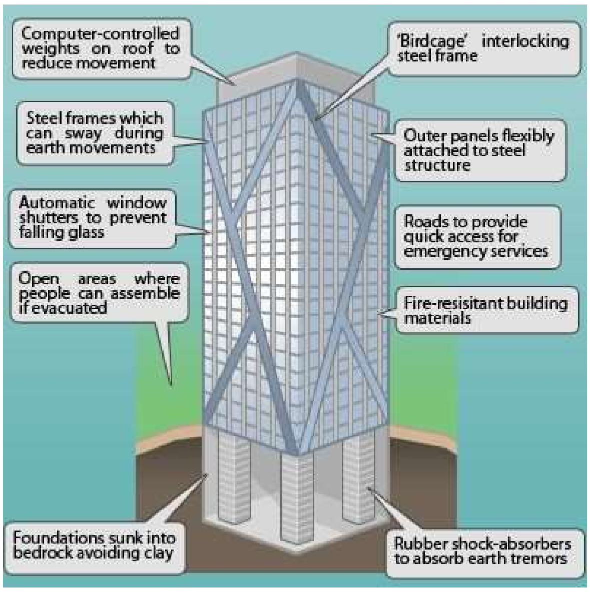
Protection

It is possible to somewhat lessen the effects of a tectonic hazard through **building design** and other means.

Volcanic eruptions can be so intense that it is often **not possible** to protect properties and infrastructure from the physical effects. **Concrete blocks** and **explosives** are sometimes used to **divert or slow lava flows**, but this is only to **redirect** the flow from one place to another, such as away from densely populated areas.

However, overall there is little that can be done to **substantially protect** any infrastructure from a lava flow or ash/debris, as seen by this lava flow in Hawaii.

(Source:www.nbcnews.com/science/environment/bombs-walls-might-slow-lava-not-stop-it-n236591



As earthquakes cannot be **predicted** with accuracy, **protecting** people and property from earthquakes is the best way to **reduce risk**.

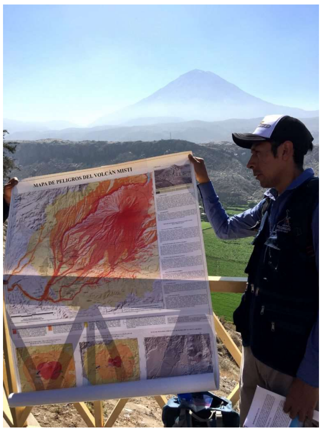
Buildings and structures can be constructed to be **resistant to intense shaking**. For example, foundations can be built **deep into the ground** and the buildings can be **reinforced** to reduce the risk of the building collapsing.

These building designs are regularly used in places with frequent earthquakes, like Japan or Chile.

Planning

In order to be **prepared well in advance** of a hazardous event, places subject to frequent tectonic hazards usually have different **plans** in place to ensure the safety of the population.

Hazard mapping is the process of dividing hazardous areas into different **levels of risk**, and changing the land use accordingly. Areas nearest the volcano or fault line are designated as the highest risk, whereas areas further away are lower risk. Therefore, **important buildings** such as hospitals or nuclear power plants can be **built away from high risk areas**. Also, hazard mapping helps when deciding **who should be evacuated** when the event happens. The picture to the right is a volcanic hazard map from Volcán Misti in Peru.



(Source: Observatorio Vulcanológico del INGEMMET (OVI), Peru. Pictured: Roger Machacca.)

Evacuation plans and safety protocols can also be developed so the population **knows what to do** if there is a hazardous event. For example, earthquake drills are often practiced in areas that experience earthquakes, and the '**drop, cover, hold on**' recommended safety action is circulated.