Edexcel Geography A-level

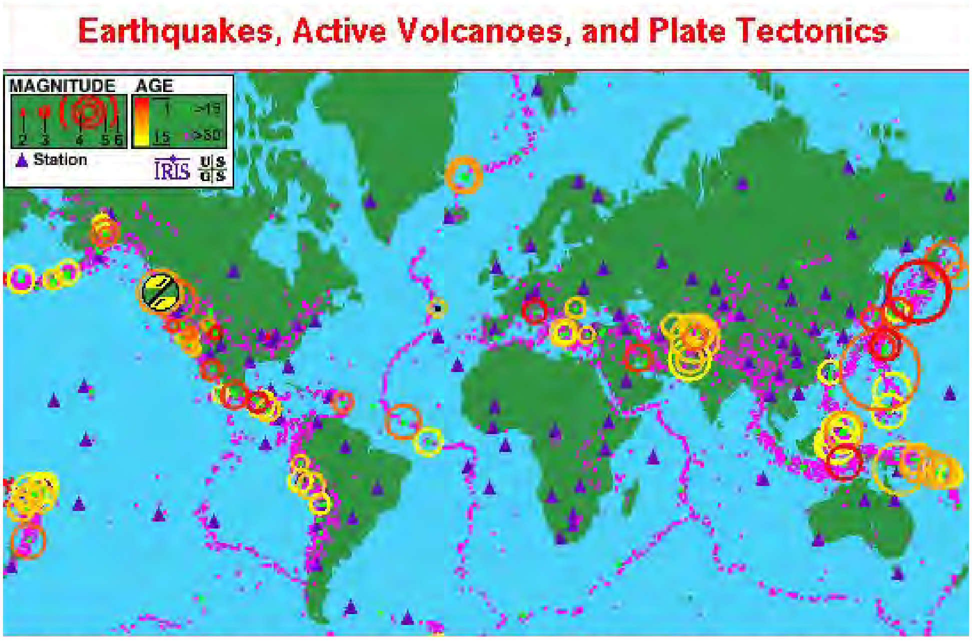
Tectonics

Essential Notes

Why are some locations more at risk from tectonic hazards?

The Global Distribution of Hazards

- A **hazard** is a potential threat to human life and property.
- A natural hazard can be either **hydro-meteorological** (caused by climatic processes) or **geophysical** (caused by land processes).



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

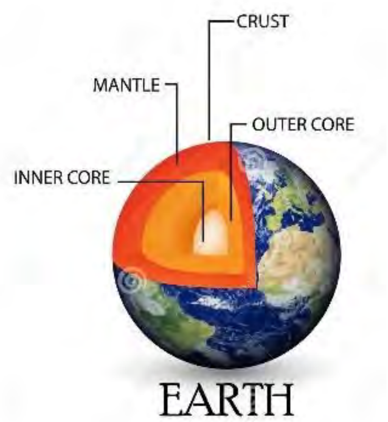


Plate Tectonics and Theories

- The Earth's structure, as shown in the picture, is divided into four sections: **crust, mantle, outer core, inner core**. The crust is divided into a series of plates. These plates are either **oceanic** (thin and dense) or continental (**thick**).
- **Radioactive reactions** occur inside the core which produces convection currents in the mantle. This causes the tectonic plates to move.
- At mid-ocean ridges, there is a push and **slab pull**. This is the process of **subduction** where oceanic plates are pushed

under continental as oceanic plates are heavier. The Pacific Plate is one such example which has a lot of subduction around its edges.

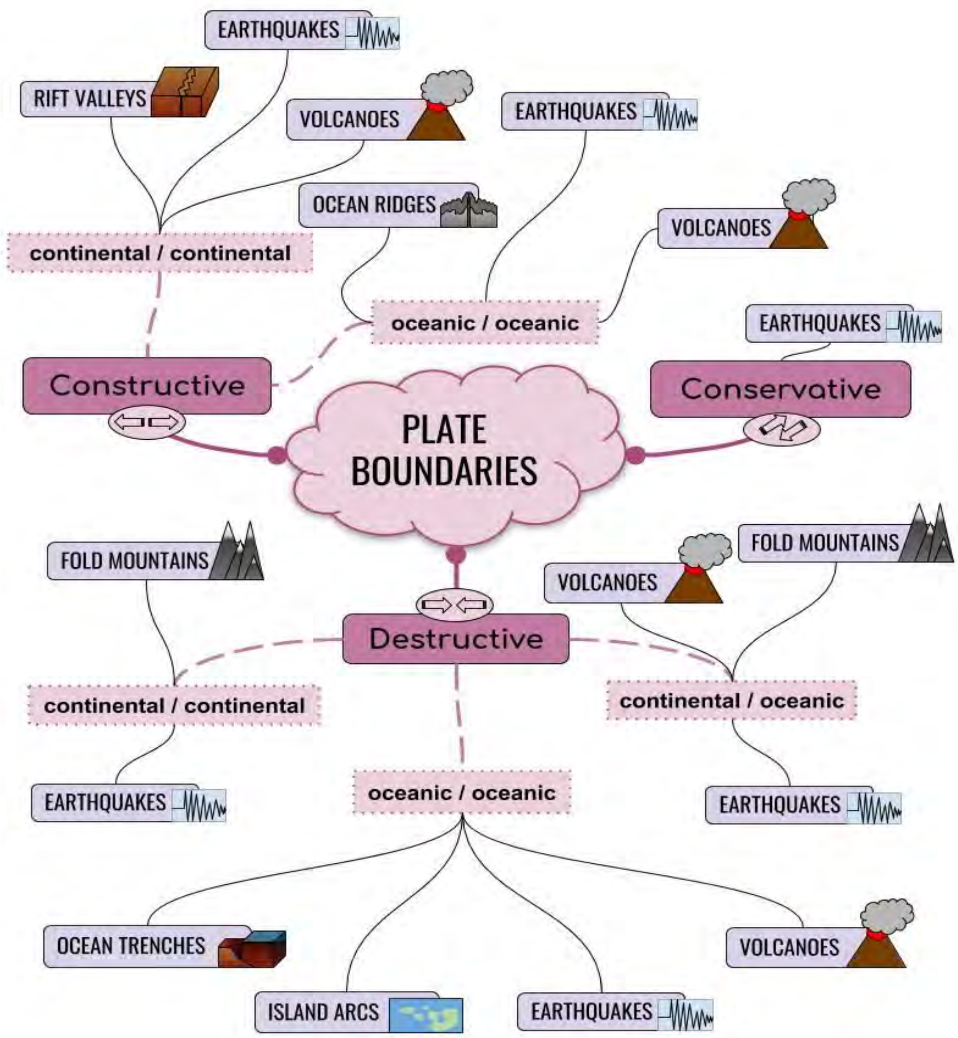
→ Plate Tectonic Theory is believed to be correct due to evidence from **Wegner's Continental Drift Theory** which states that the shapes of South America and Africa seem to fit together so were once part of a supercontinent. As plates moved, the continent separated. This is further verified by similar **fossils** found were these plates could have fit, but are now separated by oceans.

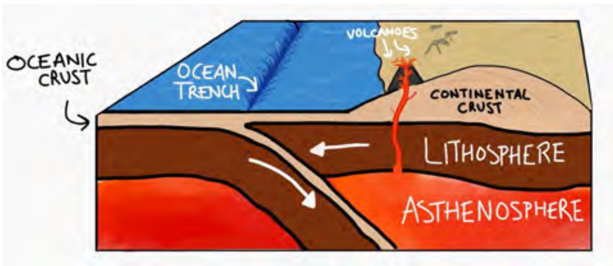
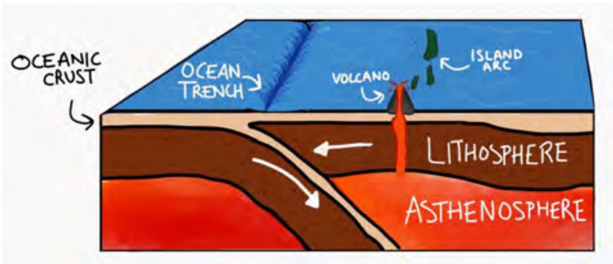
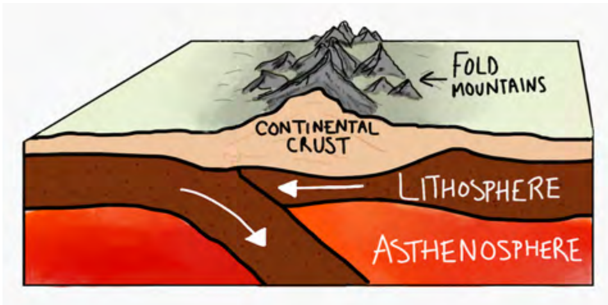
→ Another piece of evidence is studying how **seismic waves** travel through the Earth. Along the **Wadati-Benioff foci**, the depth of waves shows subduction of the denser basaltic oceanic plates into the upper mantle.

→ **Sea Floor Spreading** occurs when two oceanic plates move away from each other, allowing magma from the mantle to rise and form new crust ridges within the ocean, resulting in the sea floor widening.

→ When the magnetic patterns of cooled magma (**palaeomagnetism**) were studied, it was discovered that the magnetic patterns were arranged in the direction of the earth's magnetic field which switch every millions of years. This helps identify the age of the oceanic crust, by studying the youngest rocks at ridges, and proves that the earth did once fit together.

Plate Boundaries

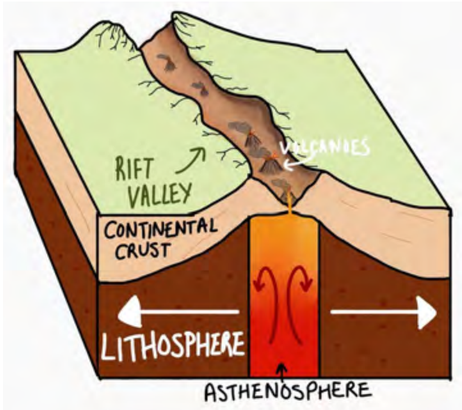


Destructive plate boundaries	
Continental and oceanic: • Denser oceanic plate **subducts** below the continental. • The plate subducting leaves a deep **ocean trench**. • Built up **pressure** from the melting plate cause explosive volcanoes bursting through the **continental plate**.	
Oceanic and oceanic: • Heavier plate **subducts** leaving an ocean trench. • Built up pressure causes **underwater volcanoes** bursting through oceanic plate. • Lava cools and creates new land called **island arcs**.	
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.	

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).	

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.



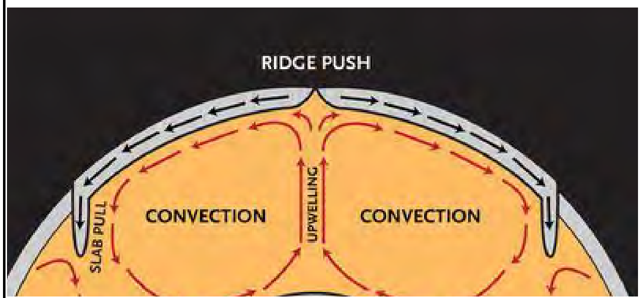
There are further forces influencing how convergent boundaries occur -

Ridge push:

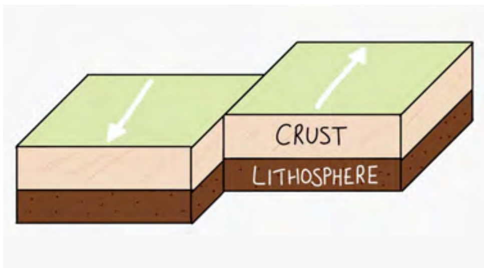
The **slope** created when plates move apart has **gravity acting upon it** as it is at a **higher elevation**. Gravity pushes the plates further away, widening the gap (as this movement is influenced by gravity, it is known as **gravitational sliding**).

Slap pull:

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



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.



Geophysical Primary Hazards

Earthquakes:

- The most powerful earthquakes occur at **destructive and conservative** boundaries.
- At constructive boundaries: Plates move at different speeds, which builds pressure until plates crack, causing **fault lines**. This results in the **release of energy** in the form of seismic waves, producing earthquakes.
- At destructive, one plate is forced under the other, getting stuck due to **friction** which produces energy. As plates suddenly jerk past one another, this energy is quickly released as **large seismic waves**, forming a powerful earthquake.
- At a conservative boundary, plates lock with one another which, when pressure is built, produces sudden seismic waves.
- Seismic waves can be split into categories. **Primary Waves** cause the immediate shock whilst **Secondary Waves** has a longer wavelength and arrives seconds later. **Love Waves** only travel through the crust, causing horizontal movement. Finally, **Rayleigh Waves** will displace the land both vertically and horizontally, due to the compressions caused in the 'rolling' Earth's crust.
- These waves can also result in **crustal fracturing** (producing faults) and secondary hazards such as **landslides, avalanches and liquefaction**.

Tsunamis:

- Tsunamis are produced by **sub-marine earthquakes** at subduction zones, causing water displacement and deep trough waves.
- This hazard is always **secondary** to earthquakes, adding to death tolls. Tsunamis present additional damage to vulnerable communities such as accelerating **coastal erosion**, which is a case in Malibu/Santa Monica in California.
- The movement of plates under the ocean causes an uplift of ocean water, disrupting the sea bed.

Volcanic Hazards:

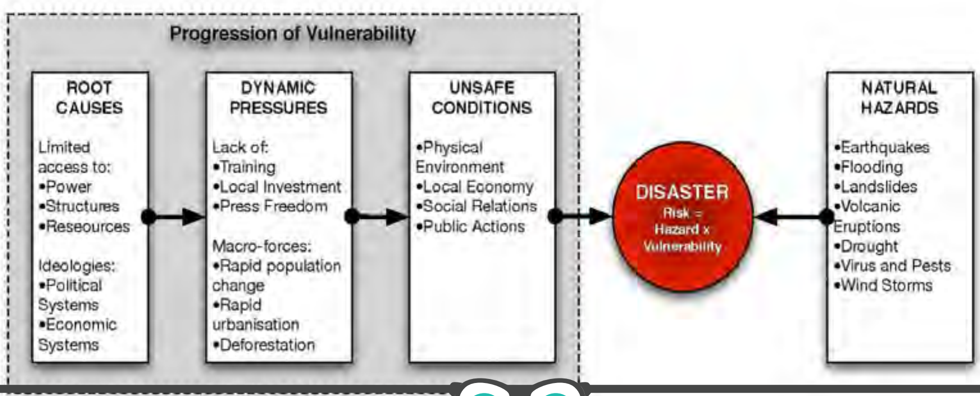
- The world's active volcanoes are found at **constructive and destructive** plate boundaries, and at **hotspots**. These volcanoes eject magma, gases, ash and dust.
- At **constructive margins**, magma is less dense than the plate so rises above it, forming a volcano, such as those within the Rift Valleys.
- At **destructive margins**, subduction causes the melting of the oceanic plate, allowing for magma to rise on the crust to form a volcano. This produces explosive volcanoes such as Mt. St. Helens in the Ring of Fire.
- The shape of a volcano determines its **destructive ability**. A super-volcano is the most destructive but seldom occurs. A **composite cone** is said to be more dangerous than a **shield volcano**.
- Volcanic hazards involve **lava flows** and **phreatic eruptions**. Away from the volcano, the greatest threats are **pyroclastic flows** which carry heated rock and ash over larger distances.
- Secondary hazards involve water in the form of **lahars** (mudflows) and **jokulhlaups** (glacial floods).

Hazards, Disasters and Vulnerability

- In 2000, 700 million were affected by 170 reported disasters.
- A **disaster** is when a hazard affects human wellbeing. **Degg's Disaster Model** suggests a disaster only happens when a hazardous event meets a vulnerable population.
- **Vulnerability** is how susceptible a population is to damage caused by a hazard. **Resilience** is how well a population can recover from a disaster.
- A **risk** is the likelihood of humans being affected by a hazard. It is determined by the **risk equation**:

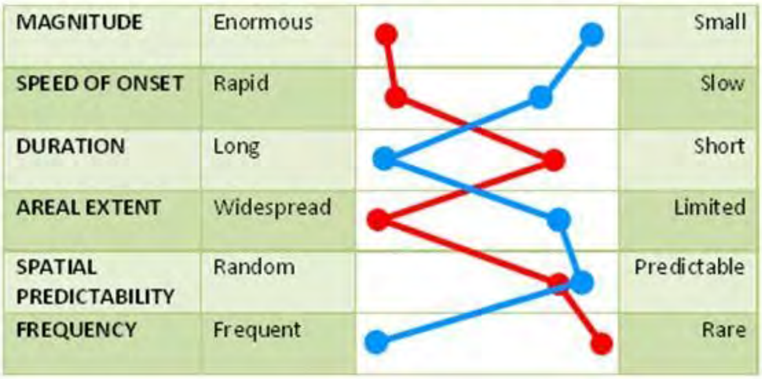
$$Risk = \frac{Hazard \ x \ Vulnerability}{Capacity \ To \ Cope}$$

- The disaster risk equation helps explain why **similar hazards cause disasters of different degrees**. For instance both Izmit (Turkey) and Kashmir (Pakistan) had a similar sized earthquake in 1999 and 2005 respectively. However, Kashmir had 75000 deaths whilst Izmit had 18000. This was because Kashmir is situated in a remote mountainous location with poor access to services/infrastructure which hinder capacity to cope.
- Thus, impacts of disasters vary according to the **levels of development**. For richer countries, there are high financial losses whilst poorer countries are left with severe shocks to community wellbeing and infrastructure. The poor are also vulnerable to secondary hazards, such as diseases, which may arise from the inability to receive international aid quickly.
- For the emerging world, such as India and China, disasters can slow growth and potentially destroy economic systems.
- The **Pressure and Release model (PAR)** proposes what should be tackled if the risk of a disaster is to be reduced.
- Vulnerability greatly influences the level of risk in the Pressure & Release Model. There are five types of vulnerability:
  - **Economic Vulnerability** - People risk losing jobs, assets or money
  - **Environmental Vulnerability** - Location is at a higher risk than others due to population pressures
  - **Social Vulnerability** - A household or community are unable to support the disadvantaged within, leaving them at risk to hazards
  - **Knowledge Vulnerability** - People lack education, training or warning of a hazard
  - **Physical Vulnerability** - Living in a hazard prone area, with buildings offering little protection



Measuring and Comparing Tectonic Hazards

- → Tectonic disasters can be measured using different scales. The magnitude of an **earthquake** can be measured using the **Richter Scale** (uses the arrival times of the primary and secondary waves) and the **Moment Magnitude Scale** which, being more accurate, uses the energy released and the movement produced by shockwaves to calculate magnitude. Both these scales are logarithmic; each level is ten times greater than the one before.
- → The intensity of an earthquake can be measured using the **Mercalli Scale** which takes into account damage produced.
- → **Volcanic eruptions** can be monitored using the **Volcanic Explosivity Index** (VEI) which uses the amount of energy released and the type of eruption to calculate a value. This scale is also logarithmic.
- → Earthquakes, volcanoes and tsunamis have different characteristics in terms of magnitude, speed of onset, duration, frequency and spatial probability. These characteristics can be used to compare different hazards, using a **Hazard Profile** (shown below).



- → Each disaster also varies in its **destructive capacity**. Impacts can be either **social, economic or environmental** as well as being direct/indirect, primary/secondary and long-term/short-term.
- → Generally, the less developed a country, the more likely it is to face more severe impacts of a tectonic hazard.

Development and Governance of a Disaster

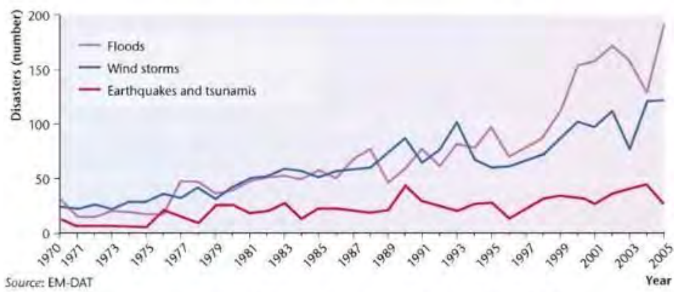
- → People remain vulnerable to disaster risks due to **inequality** in access to education, housing, healthcare and a reliable income. All of these provide safety nets in the case of a disaster.
- → Additionally pressures such as large **urbanisation** rates and **population growth** cause more people to be vulnerable to risks. Increasing **world poverty** and the **exploitation of resources** creates vulnerability and a shattered resilience for the poor.
- → The World Risk Report produced in 2014 commented that urban governments of **rapidly growing megacities**, such as Mumbai, face the major challenge of establishing planning measures to reduce vulnerability.
- → Japan's government have focused policies in disaster preparedness to reduce vulnerability and increase the capacity to cope. For instance, the '**Disaster Preparedness Day**' held annually on 1st September prepares communities for evacuation and educates them in mitigating against social or economic loss.

- For countries which are more economically developed, there is adequate public infrastructure, housing, food supplies and healthcare which, although not equally distributed, lowers the impact of a disaster.
- **Corruption government**, **poor warning systems** and **weak community strength** will exacerbate a hazard into a disaster. The government and their actions are perhaps at the pinnacle of causing or mitigating a disaster.

Management and Mitigation of Tectonic Hazards

Tectonic Disaster Trends and Patterns

- At a global scale, **deaths have decreased** whilst **economic losses have risen**. This is because the global economy and wealth has increased.
- The increased use of **international aid** and preparedness also means that less people are affected by disasters now than in 1960. However, data is based on estimates only, the exact number of deaths is often unknown. It is thus important to consider the **accuracy of data** presented.



Number of natural disasters by type, 1970–2005

- The number of tectonic disasters have **fluctuated**, having peaked in 1997 and 2000, and reaching an all-time low in the early 1980s and 2012.
- It is incredibly **difficult to predict** tectonic hazards such as earthquakes as they occur without warning. Volcanoes can be monitored for changes in shape, small eruptions which may suggest an upcoming disaster.
- Sometimes **regional disasters can become global mega-disasters**, causing widespread human and economic impacts. For instance, the 2010 Eyafjallajokull eruption in Iceland caused airline flight disruption which financially impacted both airlines and travellers globally.
- Moreover, it is estimated that **hydro-meteorological hazards** and **human induced disasters**, such as famine, have caused more fatalities than tectonic disasters, due to their slow onset.

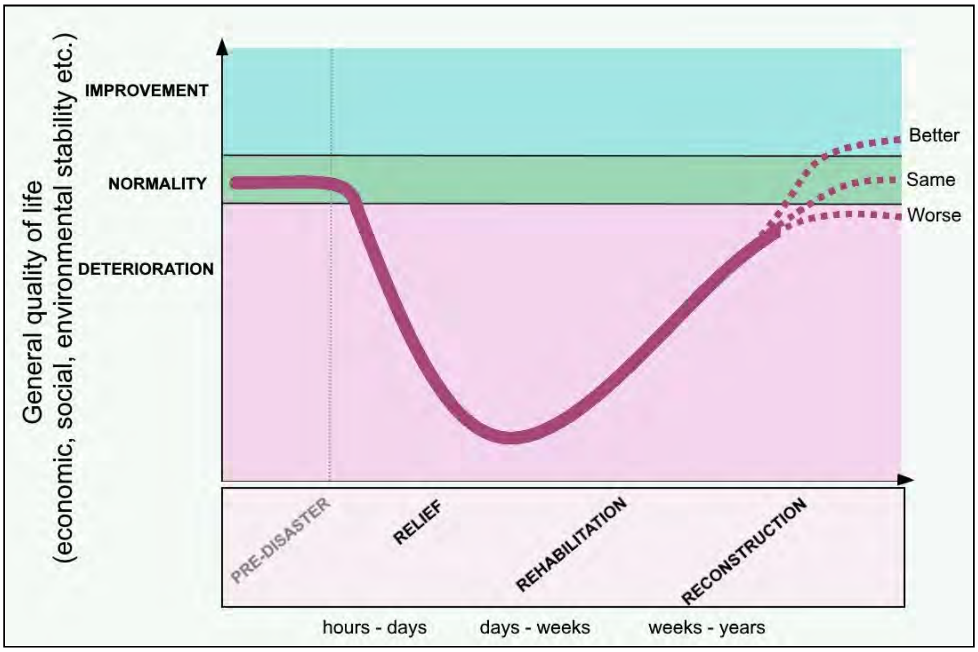
Hazard Hotspot

- For the **Philippines**, there is a complex mix of geophysical and hydro-meteorological hazards as the plate boundaries intersect a major storm belt in an area of high population density.
- The Philippines faces explosive volcanic threats (Mount Pinatubo eruption in 1991 killed 700), landslides, earthquakes, typhoons (typhoon Haiyan killed 5000 in 2013), tsunamis, drought (in 2005 on Luzon island) and flooding (1970 lowland Manila was flooded).

Prediction of Tectonic Hazards

Park's Model

- **Graphical representation** of **steps carried out** in hazard **recovery** with a rough indication of **time frame**.
- Can be used in **comparing** hazardous events (e.g. a hazardous event that is in a low income country will have a longer recovery time).
- The **steepness** of the curve shows how **quickly** an area **deteriorates** and **recovers**.
- The **depth** of the curve shows the **scale** of the **disaster** (i.e. lower the curve, lower the quality of life).



Stage 1 - Relief (hours-days)

- **Immediate** local **response** - medical aid, search and rescue
- Immediate appeal for **foreign aid** - the beginnings of global responses

Stage 2 - Rehabilitation (days-weeks)

- **Services** begin to be restored
- **Temporary shelters** and **hospitals** set up
- **Food and water** distributed
- **Coordinated foreign aid** - peacekeeping forces etc.

Stage 3 - Reconstruction (weeks-years)

- **Restoring** the area to the same or better quality of life
- Area back to **normal** - ecosystem restored, crops regrown
- **Infrastructure** rebuilt
- Mitigation efforts for **future event**

The Hazard Management Cycle

The Hazard Management Cycle outlines the stages of responding to events, showing how the same stages take place after every hazard.

Preparedness	Response	Recovery	Mitigation
Being **ready** for an event to occur (public awareness, education, training)	**Immediate action** taken after event (evacuation, medical assistance, rescue)	**Long-term responses** (restoring services, reconstruction)	Strategies to **lessen effects of another hazard** (barriers, warning signals developed, observatories)

Mitigation and Adaptation Techniques

Some governments may try to **reduce the loss** caused by a natural hazard. This can be by **modifying the event** (changing who is affected by the hazard or trying to stop any secondary hazards occuring) or by **modifying the resilience or vulnerability** of the people likely to be affected.

Strategies to modify the event:

- **Land-Use Zoning**: Create policies on where it is the safest to build infrastructure, and so reducing the population living or buildings located within high risk regions (e.g. likely to be in lava flow, in shallow bays, etc).

- **Hazard-Resistant Buildings**: Invest and produce in long-term construction projects which feature safety designs. For instance, **aseismic skyscrapers** in Japan can withstand the shock of earthquakes and stopped any fatalities in the 2011 Tohoku Earthquake.
- **Engineering Defences**: Tsunamis can be modified by creating stronger **sea walls or mangrove forests** which slow the speed of the wave. This was done at Gle Jong (Indonesia) where 70, 000 trees were planted after 2004 Indian Ocean Tsunami
- **Diversion of Lava Flows**: Lava can be diverted by spraying seawater to cool and solidify the flow. This was done in Italy to divert lava flow from Mount Etna in 1983.

The key players here are **engineers, scientists and planners** who produce and construct these defences.

Strategies to modify vulnerability and resilience:

- **Hi-Tech Monitoring**: International satellites and aircraft monitor changes in the earth, for instance GNS Science in New Zealand use light detection and ranging to create 3D data pieces of the Earth's surface. Observing changes in volcanic shapes or low magnitude earthquakes could suggest whether a disaster is likely.
- **Education**: Teaching communities about hazards and protection enables the community to gain strength and withstand shock better.
- **Community Preparedness**: Earthquakes drills and alarms prepare communities for how to best protect themselves in a disaster.

Community actions and strong governmental policies are paramount in improving the capacity to cope. Though **warning systems** can alert communities at risk, their preparedness and ability to respond to shock will inevitably determine the amount of damage done and the timescale of recovery.

Strategies to modify loss:

- **Emergency Aid**: This can be long term or short term but can make a country dependent.
- **Insurance**: Some may rely on insurance to recover losses.

Key players to modify loss are **NGOs and insurers** who can minimise loss and boost community wellbeing in the case of a disaster.