

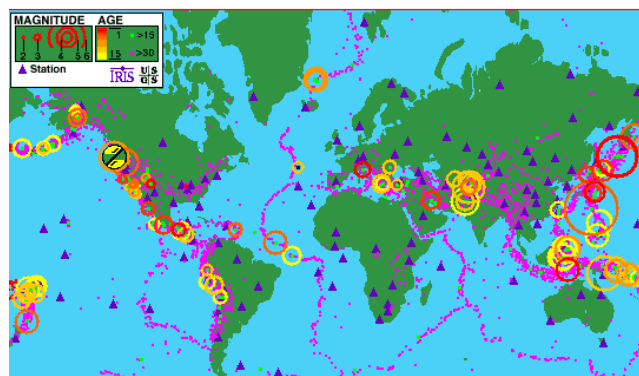
# Tectonic Processes and Hazards

## Enquiry question 1: Why are some locations more at risk from tectonic hazards?

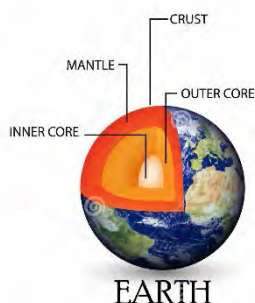
### The Global Distribution of Hazards

- 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 plates. 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).

Earthquakes, Active Volcanoes, and Plate Tectonics



### Plate Tectonics and Theories



- The Earth's structure, as shown in the picture, is divided into four sections.
- Plate Tectonic Theory:
  - The earth's 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.
- 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: This 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 flipped 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.

### Types of Plates

- Conservative – Plates move past each other but at different speeds, causing friction and collisions
- Constructive – Plates moving apart from one another

- Destructive – Plates move towards each other, colliding head on if both continental. If one is continental and the other is oceanic, subduction will occur where the oceanic plate is thrust under the continental. If there are two oceanic plates, the heavier plate will be forced under the other.

## **Causes and Impacts of Earthquakes, Volcanic Eruptions and Tsunamis**

### **1) 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 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, 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. The P waves cause the immediate shock whilst the S wave has a longer wavelength and arrives seconds later. L waves only travel through the crust, causing horizontal movement. These waves can also result in crustal fracturing (producing faults) and secondary hazards such as landslides, avalanches and liquefaction.

### **2) 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 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.
- The 1964 earthquake on the Alaskan Coast caused a northern Californian tsunami, killing 12 in Crescent City.



### **3) 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/typhoons) and jokulhlaups (glacial floods).



## Enquiry question 2: Why do some tectonic hazards develop into disasters?

### Hazards, Disasters and Vulnerability

- In 2000, 700 million were affected by 170 reported disasters.
- A **disaster** is when a hazard affects human wellbeing. Dregg'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. Capacity to cope/resilience is how well a population can recover from a disaster.
- A **risk** is the likelihood of humans being affected by a hazard. It can be calculated using the hazard risk



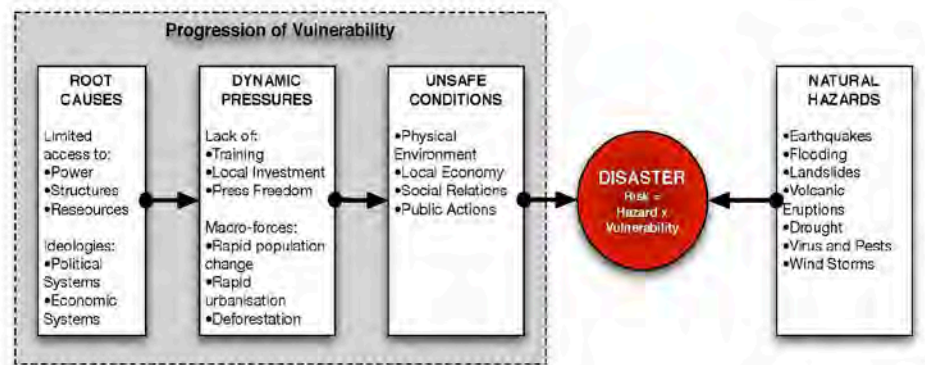
The Dregg disaster model

$$\text{Risk [R]} = \frac{\text{Hazard [H]} \times \text{Vulnerability [V]}}{\text{Capacity to cope [C]}}$$

equation. The risk of a disaster increases as the frequency/severity of the hazard increases along with vulnerability whilst the population's capacity to cope decreases.

- Qatar has the lowest disaster risk (at 0.1%) whilst Philippines has the highest (at 27.5%) out of 170 countries.
- 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 here is the major factor which can be controlled to prevent disasters from occurring. Vulnerability can be physical, economic or social in nature, showcasing the complex interaction between causes, pressures and conditions which all work to exacerbate the impact of natural hazards.



### 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 P and S 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** 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. The diagram showcases a hazard profile, comparing the 2004 Asian Tsunami with the volcanic eruption of Kilauea on Hawaii.

MAGNITUDE	Enormous		Small
SPEED OF ONSET	Rapid		Slow
DURATION	Long		Short
AREAL EXTENT	Widespread		Limited
SPATIAL PREDICTABILITY	Random		Predictable
FREQUENCY	Frequent		Rare

→ Each disaster also varies in the destruction it causes.

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 social and economic impacts of a tectonic hazard.

→ For example, both California and the Philippines are disaster hotspots but whereas 40 to 60% lie below the poverty line in the Philippines, only 20% do in California. This means that, in the case of a disaster, the Philippines will have greater social impacts (as most infrastructure is damaged and international aid is needed) whilst California will face larger economic losses.

→ The diagram to the left showcases the contrasting impacts of the 2004 tsunami for each affected country.

### The Boxing Day tsunami, 2004

**Maldives**  
Of the 199 inhabited islands, 20 were destroyed. The shallowness of the water limited the tsunami's destructive power but flooding was extensive. A sea wall protecting the capital Male prevented half the city being destroyed. Many luxury tourist resorts were badly damaged – affecting the economy of the country, which depends on tourism. 82 dead or missing.

**Somalia**  
This was the worst-hit African country, with damage concentrated in the top of the Horn of Africa. Homes and boats were destroyed and freshwater wells and reservoirs were contaminated. Up to 30 000 people were displaced and 150 people dead or missing.

**India**  
The south east coast of the mainland, especially Tamil Nadu, was worst affected. Up to 140 000 people were displaced. In the Andaman and Nicobar Islands, salt water contaminated freshwater sources and destroyed arable land. Most of the Island's jetties were also destroyed. 16 513 dead or missing.



**Thailand**  
The west coast was severely hit, including islands and tourist resorts near Phuket, so the death toll included 1700 foreigners from 36 countries. 5395 dead or missing.

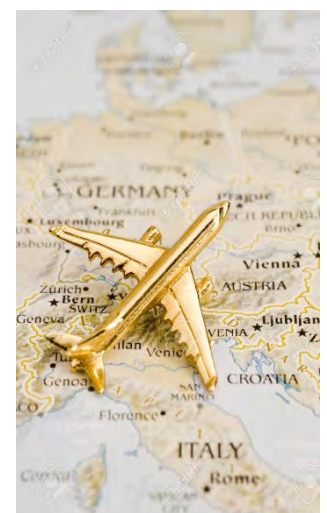
**Indonesia**  
Western Sumatra, the closest inhabited area to the earthquake's epicentre, was devastated by the tsunami. Up to 70% of some coastal populations were killed or missing. Up to 400 000 people were displaced. 236 169 dead or missing.

**Kenya**  
Kenya was one of the few affected countries to be warned and to take some action, so many people were able to escape the coastal areas as a result – and only one person was killed.

**Sri Lanka**  
The second worst affected country – the southern and eastern coastlines were ravaged, with homes, crops and fishing boats destroyed. 400 000 people lost their jobs. 31 147 dead or missing.

### The Role of Development and Governance on Disaster Impact

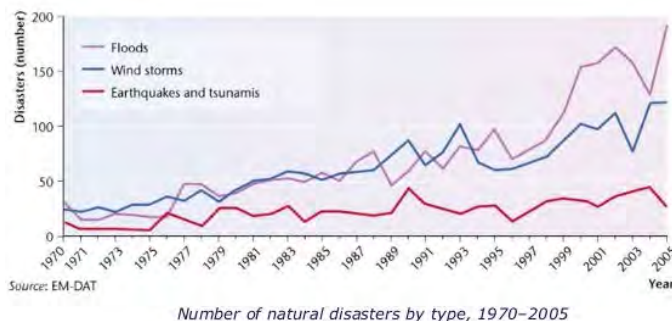
- People remain vulnerable to disaster risks due to inequality in access to education, housing, healthcare and a reliable income. All of these provide safety nets in the case of a disaster.
- Additionally pressures such as large urbanisation rates and population growth mean more are vulnerable to risks whilst 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 cities, 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' each year prepares communities for shock.
- 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.
- Moreover, a corrupt government, poor warning systems and weak community strength will mean a hazard is more likely to turn into a disaster. The government and their actions are perhaps at the pinnacle of causing or mitigating a disaster.



## Enquiry question 3: How successful is the management of tectonic hazards and disasters?

### Tectonic Disaster Trends and Patterns

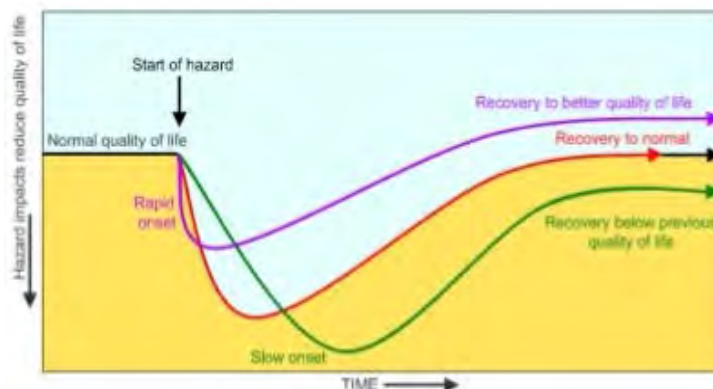
- At a global scale, deaths have decreased whilst economic losses have risen. This is because the global economy and wealth is greater now than it was before.
- The use of international aid and preparedness also means that less people are affected by disasters now than in 1960. However, data is based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

- Prediction accuracy depends on the type of tectonic hazard; a volcano can be monitored for likely eruptions but tectonic plates move randomly so earthquakes cannot be predicted accurately.
- The United Nations Office for Disaster Risk Reduction stresses on the importance of improving a community's resilience to natural hazards. They highlight the vitality of adopting multiple management techniques (e.g. preventing floods by utilising sandbags on coasts whilst improving warning systems) to prevent hazards from becoming disasters.
- Park's model (shown on right) takes into account that different hazard events have different impacts so vary in their duration, speed and destruction of quality of life. The three different lines are representative of a country's response and ability to manage the disaster. The less developed a country, the greater the impacts and destruction of quality life. The disaster onset is also slower as secondary hazards worsen death tolls.



## Mitigation and Adaptation Techniques

### → Strategies to modify the event:

- Land-Use Zoning: Create policies on where it is the safest to build infrastructure.
- Hazard- Resistant Design: Invest and produce in long-term construction projects which feature safety designs. For instance, certain buildings in Japan can withstand the shock of earthquakes.
- 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
- 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. Changes to the surface pinpoint the likelihood of a disaster.



- Prediction: 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.

The key players here are NGOs and insurers who can minimise loss and boost community wellbeing in the case of a disaster.



## Key Words

**Geophysical hazard:** A hazard formed by tectonic/geological processes (earthquakes, volcanoes and tsunamis)

**Hazard:** A perceived natural event which has the potential to threaten both life and property

**Hydro-meteorological hazard:** Formed by hydrological (floods) and atmospheric (storms and droughts) processes

**Vulnerability:** A high risk combined with an inability of individuals and communities of cope

**Disaster:** A hazard becoming reality, causing deaths and damage to goods/property and the environment

**Risk:** The probability of a hazard event occurring and creating loss of lives and livelihoods

**Frequency:** How often an event of a certain size (magnitude) occurs.

**Magnitude:** The size of the event (e.g. size of an earthquake on the Richter scale)