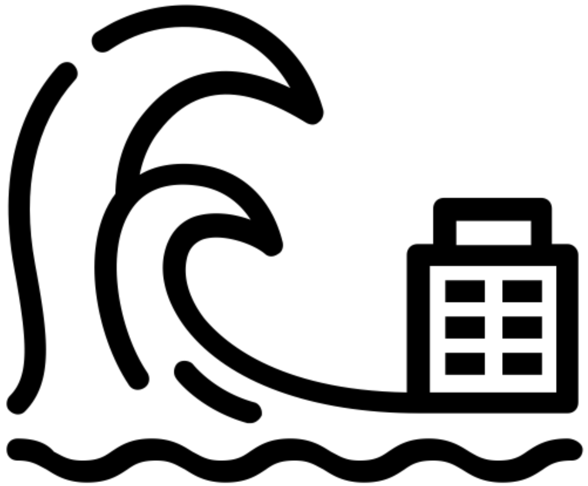
MSN 2020

3.1

Year 12

Module 3P

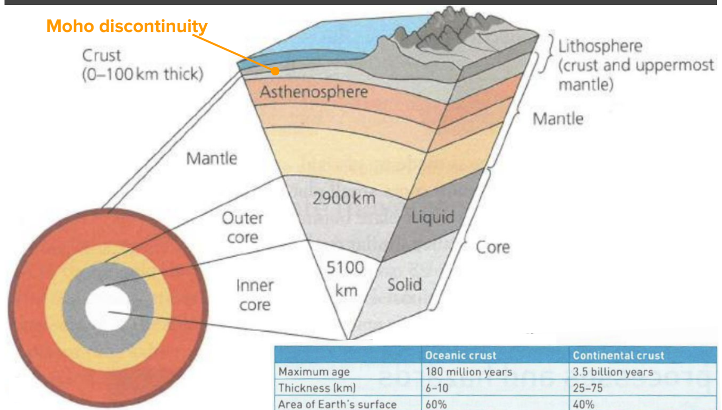
Tectonic Hazards



Geography Knowledge Organiser

3.1.1 - Tectonics

Structure of the Earth



	Oceanic crust	Continental crust
Maximum age	180 million years	3.5 billion years
Thickness (km)	6–10	25–75
Area of Earth's surface	60%	40%
Density ($g\,cm^{-3}$)	3.3	2.7
Rock type	Basaltic	Granitic

Tectonic theory

Convection currents

Original tectonic theory stated that the rising limb of convection currents spread out to the sides under the plates and pulled the plates along with it. However, modern research has not found strong enough convection currents to confirm this theory

Slab pull / ridge push

New research suggests that the denser, older oceanic plate is pulled under (subducted) by gravity, this is called **slab pull**. As two plates move away (diverge), magma rises up and pushed the 2 plates away from each other this is called **ridge push**. However, we now think ridge push isn't actually strong enough to push plates

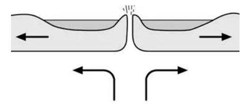
Plate settings

Tectonic setting	Motion (processes)	Hazards	Example	Landforms
Constructive plate boundaries (divergent margin)	Two oceanic plates moving apart	Basaltic volcanoes and minor, shallow earthquakes	Mid-Atlantic ridge (Iceland), mostly submerged	Lava plateaux Ocean ridge features
	Two continental plates moving apart	Basaltic spatter cones and minor earthquakes	Mt Nyiragongo (DRC) in the East African Rift Valley	Rift valley landscapes
Destructive plate boundaries (convergent margin)	Two oceanic plates in collision	Island arc explosive andesitic eruptions and earthquakes	Soufrière Hills on Montserrat, Aleutian Islands	Island arcs of volcanoes
	Two continental plates in collision	Major, shallow earthquakes, long thrust faults	Himalayan orogenic belt collision zone	Compressional mountain belts
	Oceanic and continental plates in collision	Explosive, andesitic eruptions and major earthquakes	Andes mountain chain and volcanoes	Complex mountain landscapes with fold mountains and volcanoes
Transform boundaries (conservative margin)	Plates sliding past one another	Major shallow earthquakes No volcanic activity	San Andreas fault, California, North Anatolian fault, Haiti	Strike-slip faulted landscapes
Hotspots	Oceanic	Basaltic shield volcanoes and minor earthquakes	Hawaiian island chains, Galapagos Islands	Volcanic landscapes
	Continental	Colossal rhyolitic mega-eruptions	Yellowstone 'supervolcano', USA	'Roots' of super volcanoes

Constructive plate margins

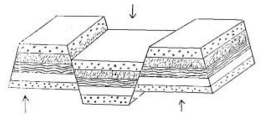
OCEANIC-OCEANIC

Slab pull causes the plates to diverge, bringing magna up from the asthenosphere. This cools on the sides of the plates forming **ocean ridges** and **submarine volcanoes**



CONTINENTAL-CONTINENTAL

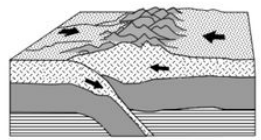
Slab pull causes the plates to diverge, buoyancy of plate edges, forces land up. Subsidence occurs blocks of the plate sink creating liner mountain ranges (**ridges**) and steep, straight-sided valleys, called **rift valleys**



Destructive plate margins

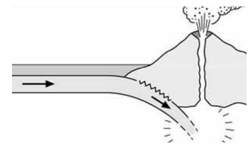
OCEANIC-OCEANIC

When 2 oceanic plates converge, the older, denser plate subducts, melting the plate in the mantle. This creates additional magma which rises through the plate to form chains of **volcanoes** and islands (**island arcs**). Gaps between the plates are very deep valleys called ocean trenches. As the plates move past each other, friction builds in the **benioff zone**, creating **earthquakes**



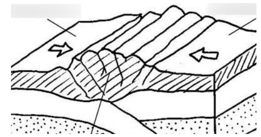
OCEANIC-CONTINENTAL

When oceanic plates converge with continental , the oceanic plate always subducts. The process is the same as above, however the continental plate does buckle and fold to create **fold mountains**



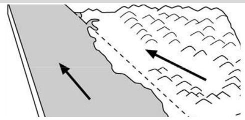
CONTINENTAL-CONTINENTAL

When 2 continental plates converge, none subduct (both same density) - **collision margin**. Ocean sediments caught between the 2 plates are compressed and forced upward (**thrust faults**) creating **complex mountain formations**. Earthquakes do occur, but as no plates are subducting, no volcanoes occur here.



Conservative plate margins

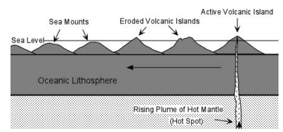
2 plates moving laterally past each other (**transform**). No crust is subducted so there are no volcanoes, however there is a lot of friction where the plates move past each other (**fault**) creating frequent but low magnitude **earthquakes**.



Hot spots

OCEANIC

Found away from margins (in plate centres). Areas with strong magma plumes (**hot spots**) melts through thin crust allowing magma to extrude. Over time creating **volcanic islands** in chains. As volcanoes move away from the hot spot they are eroded by the sea becoming **sea mounts**



CONTINENTAL

The same process above, but no island chains. Producing large calderas, such as supervolcanoes.

Hazard profiles

Magnitude of earthquakes	<u>Moment Magnitude</u> (MM) *measures energy released*
Magnitude of volcanic eruptions	<u>Volcanic explosivity index</u> (VEI) *rates characteristics*
Frequency	*How often the event occurs (recurrence rate)*
Areal extent	*Size of the area covered by the hazard (distance)*
Spatial concentration	*Locations covered by the hazard (places)*
Duration	*Length of time the hazard exists (time)*
Speed of onset	*How much warning before a hazard (speed)*
Predictability of occurence	*How predictable is the next hazard (Predictability)*

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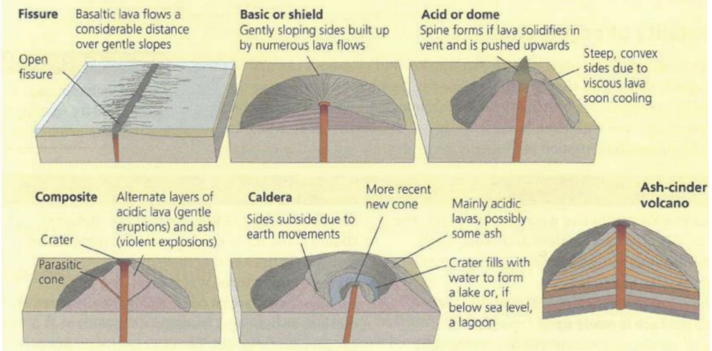
3.1.2 - Volcanoes

Types of volcanoes



Major categories of eruptions

	Category	Description
Effusive	Icelandic	Lava flows directly from a fissure
	Hawaiian	Lava is emitted gently from a vent
	Strombolian	Small but frequent eruptions occur
	Vulcanian	More violent and less frequent
	Vesuvian	Violent explosion after a long period of inactivity
	Krakatoan	Exceptionally violent explosion
	Pelean	Violent eruption of pyroclastic flows (nuées ardentes)
Explosive	Plinian	Large amounts of lava and pyroclastic material are ejected

Associated hazards

Pyroclastic flows (nuées ardentes)

Hot gases and ash surge downhill. Upto 1000°c, at 33ms^{-1} for 40km. There is no warning and kills immediately by external and internal burn and asphyxiation

Lava flows

Lava poses more of a threat to property than people. Basaltic lava can flow up to 15ms^{-1} where as thicker lava is much slower and travels less distance

Tephra (ash falls)

Fragments of material ejected by the volcano, This can be tiny fragments like ash or large stones (bombs). Causing breathing problems, collapsing infrastructure and transport issues

Volcanic gases

From eruption and cooling lava. Water vapour, hydrogen, carbon monoxide, sulphur dioxide, chlorine, hydrogen chloride & hydrogen sulphate

Volcanic landslides

Slides of the volcano or nearby cliffs which collapse due to tremors caused by the eruption or lava or lahars flows.

Lahars

Ash, mud and rainwater or snow melt mixed as a dense, viscous flow. Fast flowing due to steepness of volcano sides. Capable of submerging entire settlements.

Jökulhlaups

In subglacial eruptions, glacial melt water is trapped in a lake between the glacial and the volcano. Upon eruption the water is released as a potential violent flood

Primary
Secondary

Impacts of volcanic hazards

Human impacts

The following is the average losses per year (1975-2000):

People dead: 1,019
People injured: 285
People made homeless: 15,128
People affected: 94,399
Estimated damage: $0.065bn

hazard event x vulnerability of people = adverse consequences, harm or loss

Environmental impacts

Increased precipitation (H_2O given off during eruption)
Stratospheric warming (absorption of short & long wave radiation)
Global cooling (absorption of shortwave radiation)
Ozone depletion (Dilution, heterogeneous chemistry and aerosol)
Reduction of diurnal cycle (blocking shortwave radiation and emitting longwave radiation)

3.1.3 - Earthquakes

Earthquake characteristics

Most earthquakes result from movement along fractures or faults in rocks. These faults usually occur in groups called a fault zone which can vary in width from a metre to several KM. Movements occurs along fault planes of all sizes as a result of stresses created by crustal movement The stresses are not usually released gradually but build up until they become so great that the rock shifts suddenly along the fault.

- As the fault moves the shockwaves produced are felt as an earthquake by a process known as **elastic rebound**
- The point/origin of the break is called the **focus** or hypocentre which can be shallow to deep focus up to 700km deep
- If stresses are released in small stages there will be a series of smaller earthquakes
- If the stresses build up without being released there is the possibility of a major earthquake – the 'Big One'

Primary (P) waves	P waves are vibrations caused by compression. They spread out from the earthquake fault at a rate of about 8kms^{-1} and travel through both solid rock (Earth's core) and liquids (oceans)
Secondary (S) waves	S waves move through the Earth's body at about half the speed of P waves. They vibrate at right angles to the direction of travel. S waves, which cannot travel through liquids, are responsible for a lot of earthquake damage
Rayleigh (R) waves	R waves are surface waves in which particles follow an elliptical path in the direction of propagation and partly in a vertical plane — like water moving with an ocean wave
Love (L) waves	L waves are similar to R waves but move faster and have vibration solely in the horizontal plain. They often generate the greatest damage, as unreinforced masonry buildings cannot cope with horizontal accelerations

The overall severity of an earthquake is dependent on the amplitude and frequency of these wave motions. S and L waves are more destructive than P waves because they have a larger amplitude and force. Therefore in an earthquake the ground surface may be displaced horizontally, vertically or obliquely depending on the wave activity and geological conditions.

Associated hazards

Ground movement & ground shaking

Surface seismic waves represent the most severe hazard to humans and their structures since buildings and other structures may collapse and kill or injure occupants. Near the epicentre ground motion is both severe and complex as there is an interlocking of both P and S waves and therefore most damage should theoretically occur at the epicentre

Tsunamis

Tsunamis are the most destructive secondary earthquake hazard. Caused along submarine destructive margins. When the stressed plate is released (during a magnitude 6+), it displaces a column of water above which moves out in all directions carrying huge volumes of water - only stopping when it reaches land

Liquefaction

Associated with loose sediments; water saturated material loses strength and behaves like a fluid due to strong ground shaking which increases the water pressures in the pores. The shaking causes loose sediments to settle and compact reducing pore spaces in lower layers so water is forced into upper layers of the ground.

Landslides & avalanches

Severe ground shaking causes natural slopes to weaken and fail. Causing deaths, injury and hampering relief efforts. This can happen with rock or snow. Landslides are a particular risk after an earthquake as aftershocks occur and the ground finds a new resting position.

Impacts of seismic hazards

Human impacts

The following is the average losses per year (1975-2000):

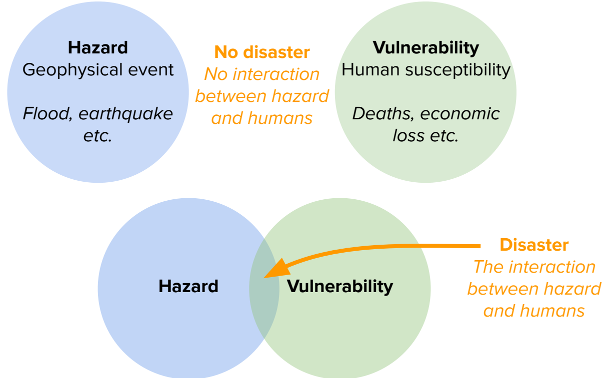
People dead: 18,416
People injured: 27,585
People made homeless: 239,265
People affected: 1,590,314
Estimated damage: $21.5bn

Environmental impacts

Air pollution (fires and leaking gas mains)
Water pollution (leaking sewage systems)
Farmland/crops affected (broke irrigation system or covered in rubble)
Pest infestations (decomposing organic material attracts flies and rats)
Death if marine wildlife (tsunami waves kill animals in the sea)

3.1.4 - Risk and vulnerability

Disaster vs hazard



Dregg model

Risk

Risk - the probability of a hazard occurring and creating loss of lives and livelihoods

The risks of a tectonic hazard is both involuntary and consciously decided by people, for example:

- unpredictability of hazards: areas may not have experienced a hazard in living memory
- the changing risk over time (e.g. a perceived extinct volcano)
- lack of alternative locations to live, especially for the poor
- an assessment that economic benefits outweigh the costs, eg. for area of rich volcanic soils or of great tourism potential
- optimistic perceptions of hazard risks: it can all be solved by the technofix, or it won't happen to me

Risks can be altered by human conditions and actions, for example 2 earthquakes for the same magnitude will produce different risks.

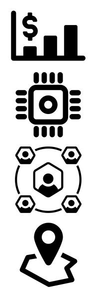
Vulnerability

Vulnerability - the degree of resistance offered by a social system to the impact of a hazardous event. This depends on the resilience of individuals and communities, the reliability of management systems and the quality of governance that have been put in place.

Risk equation

$$\text{Risk} = \frac{\text{Frequency and/or magnitude of hazard} \times \text{level of vulnerability}}{\text{Capacity of population to cope (ie. resilience level)}}$$

Drivers of disaster and vulnerability



Economic factors
Poorest, least developed countries lack money to invest in education, social services, infrastructure and technology
Technology factors
Technology is used for preparedness and education but also in solutions for building designs and prediction, preventions and monitoring equipment
Social factors
Population density, demographic (age), quality of housing
Political factors
Lack of strong central government or weak organisational structure leads to poor preparation or responses
Geographical factors
Relief, time of day, multi-hazard locations, rural.urban areas

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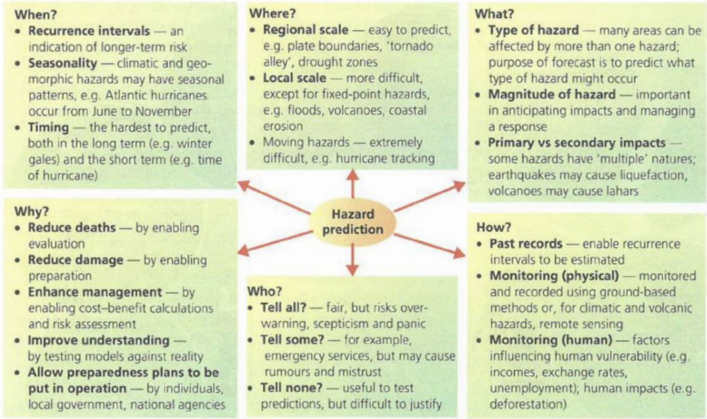
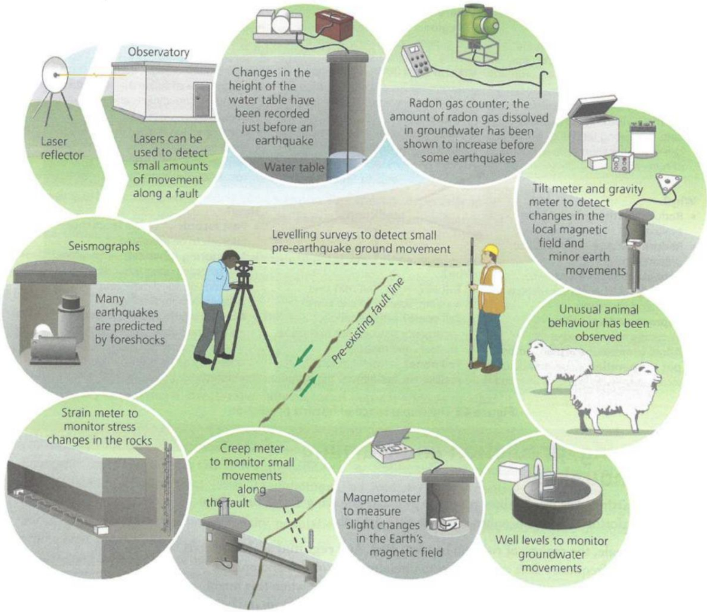
3 . 1 . 5 - Hazard responses



Monitoring, prediction and warning of earthquakes



Monitoring, prediction and warning of volcanoes

Earthquake activity
Earthquake activity is common before eruptions
Ground deformation
A forerunner to explosive eruptions - tilt meters are used to measure ground deformation
Global positioning systems
Satellites captures chances in ground level during each pass of the volcano
Thermal changes
Ground observation of hydrothermal phenomena such as increased discharge in hot springs, stream from fumaroles or temperature of crater lakes
Geochemical changes
Detecting composition of gases issuing from volcanic vents (SO_2 H_2S)
Lahars
Seismometers detect ground vibrations from an approaching lahar and sound early warning systems

Prediction and warning of tsunamis

Global-scale warning systems
In 1948 the Pacific Warning System for 24 Pacific Basin nations was established, . with its centre near Honolulu in Hawaii. Seismic stations detect all the earthquakes and their events are interpreted to check for tsunami risk. The aim is to alert all areas at risk within 1 hour. The time it takes for a wave to travel across the Pacific . allows ample time to warn shipping and evacuate low-lying coastal areas. As not all earthquakes result in tsunamis, it is a difficult decision whether to issue a warning.

Regional-scale warning systems
Regional-scale warning systems aim to respond to locally generated tsunamis with short warning times as these pose a much greater threat. Ninety percent of tsunamis occur within 400 km of the source area, so there may be less than 30 minutes between tsunami formation and landfall. Japan has the most developed system - the target is to issue a warning within 20 minutes of the approach of a tsunamigenic earthquake within 600km of the Japanese coastline.

Mitigation and adaptation of tectonic hazards

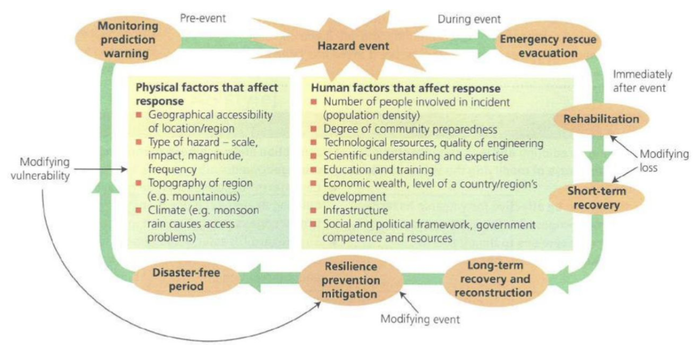
Modify the event
Changing the event in such a way that reduces the impact. This can be through modifying buildings to be earthquake and/or tsunami-proof, developing resistant infrastructure or event using seawater to cool lava and slow its speed or change the course. However actually reducing the ground shaking or violence of an eruption is impossible

Modify the vulnerability
Use of prediction, warning and monitoring to education and prepare people for a potential hazard. The use of land use planning and layout to locate key infrastructure away from potential hazards. Keeping population densities reduced in high risk areas or rezoning areas like coastlines are parks and farming rather than residential and business to reduce the impact of tsunamis

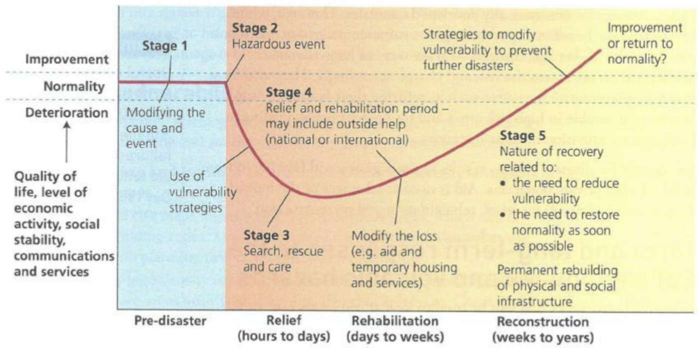
Modify the loss
The use of aid, and insurance to recover quickly after the hazard event

Short and long-term responses to tectonic hazards

Hazard disaster management cycles



Park's disaster-response curve model



Home study questions

DEVELOPING

Outline the difference in characteristics of oceanic and continental crust **[4 marks]**

Explain the processes occurring at destructive plate margins **[6 marks]**

SECURING

Analyse how different seismic waves affect the impact of earthquakes (3 . 1 . 3) **[6 marks]**

Explain why lahars are a secondary effect of volcanoes **[4 marks]**

MASTERING

'Secondary impacts of volcanic eruptions present a greater box long-term threat to people than primary impacts?' **To what extent** do you agree with this statement? **[15 marks]**

Assess the relative usefulness of the Park Model and the Hazard Management Cycle in understanding the impact of seismic events**. [15 marks]**

CHALLENGE

Create a completed Dreggs model to show the hazards and vulnerabilities of the Southeast Asian tsunami (research the case study) (3 . 1 . 4)

Research real-world example of the 6 different types of volcanoes