Subject	Geography	Year Group	12	Sequence No.	1	Topic	Hazards

Retrieval	Core Knowledge	Student Thinking
What do teachers need retrieve from students before they start teaching new content?	What specific ambitious knowledge do teachers need teach students in this sequence of learning?	What real life examples can be applied to this sequence of learning to development of our students thinking, encouraging them to see the inequalities around them and 'do something about them!'
Each lesson starts with a recap of prior knowledge Link back to Y8 geography and GCSE geography when considering what a hazard is Students to consider and discuss which places they have learnt about GCSE	**<u>What is a hazard?</u>** When a natural or human event occurs that causes disturbance to the natural environment Different types of hazards Geophysical hazards natural hazards caused by the physical processes or phenomena that act upon, or within the Earth-earthquake, volcano Atmospheric hazard natural hazards caused by extremes linked to air and the weather e.g hurricane, drought Hydrological hazards are hazards associated with water e.g floods, tsunami **Nature:** The causes and characteristics of an event **Form:** The specific type/classification of an event **Impacts:** The effects/consequences of an event **<u>What factors influence the way we respond to natural hazards?</u>** • Human perception-How do people perceive the hazard? Do hazards occur frequently where they live? As that can influence how they respond. • Human responses-Some countries have better response strategies in place than others • Fatalism-Accepting what happens and not taking any action to deal with it. This could be due to religious views, wanting the environment reach a state of equilibrium • Prediction & Adaptation-how to do people change their behaviours and way of living to help to respond to hazards **<u>Hazard management cycle</u>** • The Hazard Management Cycle takes into account preparedness, response, recovery and mitigation.	From the knowledge gained in this topic students will understand how hazards could impact them in their life as well as how hazards can impact less developed countries more. Students will explore how problems linked to hazards can be solved. This will also look into a career they could have linked to the knowledge aquired. They will do this through the following activities: • Examine real life examples of places that have been impacted by hazards in order to have empathy. • Students create a fact file of natural hazards that are taking place in

<table>
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<td>that link to the factors that influence the way people respond to natural hazards

Students will recap from KS3 and GCSE the different layers of the Earth

From GCSE students retrieve knowledge regarding the plate tectonic theory

From KS3 and GCSE students retrieve the different plate margins

From KS3 and GCSE retrieve hazard management strategies

Link hazard management to the management models from earlier in the topic</td>
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- The disaster cycle or the disaster life cycle consists of the steps that emergency managers take in planning for, and responding to, disasters.
- Each step in the disaster cycle correlates to part of the ongoing cycle that is emergency management. This disaster cycle is used throughout the emergency management community, from the local to the national and international levels
- Preparedness strategies focus on ensuring that emergency services and people at risk are aware of how to react during an event. After the hazard happens response then happens.
- The response section of the hazard cycle is focused on the immediate needs of the population, such as the protection of life and property and includes firefighting, emergency medical response, evacuation and transportation, decontamination, and the provision of food, water and shelter to victims.
- Recovery is the equivalent to long-term responses and is where the city authorities focus on clean-up and rebuilding. This can take months or even years.
- Finally, mitigation involves authorities looking at the impact of the hazard and rebuilding in a better way to reduce similar impacts from a future hazard. This can involve the building of earthquake proof buildings for example. Recovery and mitigation take place at the same time. After the cycle is complete, emergency planners will revisit the cycle and review and amend the aspect of preparedness in light of the success of the responses in the recent hazard.

<u>The Parks Model</u>
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<td>the world over a 14-week period.

- Students to discuss how effective the models are and how different countries at differing stages of development can use them.
- TedEx linked to risk resilience in the world today
- Students are given podcasts and documentaries to watch and make notes on linked to current and real life events and research
- Geography in the news articles
- Students will discuss what we can do in society today to help deal with natural hazards
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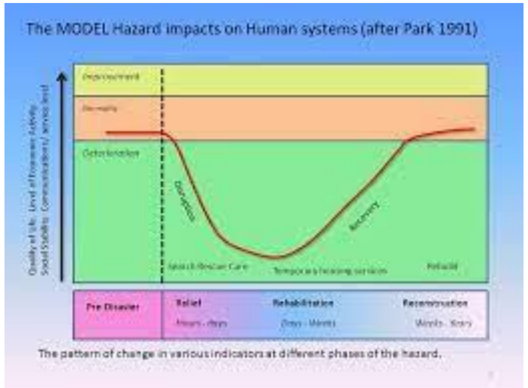
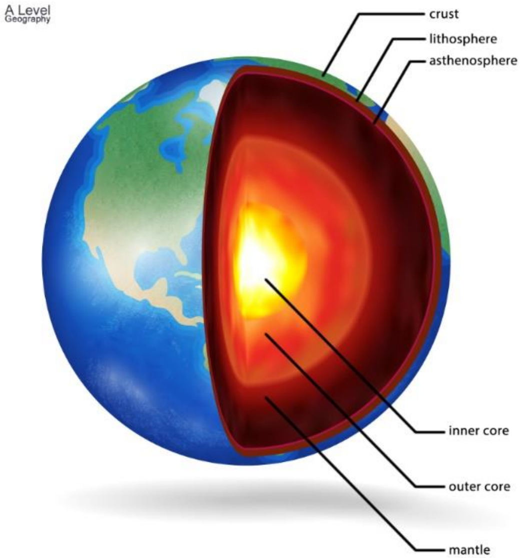
From KS3 and GCSE retrieve knowledge linked to the causes, effects and management of earthquakes From earlier in the topic link back to the plate tectonic theory when exploring earthquakes Retrieve from GCSE the causes, effects and management of tropical storms Retrieve from GCSE geog the frequency and predictability of tropical storms Retrieve from Y8 Geography causes, impacts and management of wildfires Make links with human geography topics such as place when discussinh how hazards can	• The Park model is also known as the disaster response curve. Its aim is to show the effects of a hazard on quality of life over a sequence of time. Stage 1 • Occurs prior to the event and shows that quality of life is at its normal equilibrium level. Stage 2 • Where the hazard occurs and, again, at this point quality of life is at normal level. Stage 3 • Where the event has happened and search and rescue is underway. Quality of life drops at this stage and stays low for several hours up to several days depending on the severity of the hazard and the level of development of the region/country. Stage 4 • Where relief strategies are underway and there is an organised programme of help. It can take a variable amount of time, from hours and days to weeks and months to reach this stage, but quality of life improves at this time. Stage 5 • Refers to long term human response; rebuilding and restoring normality. Quality of life returns to normal and in some cases can be higher than it was originally; especially if the repairs improve on the old infrastructure etc 	

alter peoples perception of place Also, when looking at management and responses to natural hazards link to global governance and the use of UN, IMF WB etc Discuss stages of development and how that impacts how successfully a country can respond	**<u>How could heat be linked to the causes of geophysical hazard?</u>** Earth's internal heat powers most geological processes and drives plate tectonics.  Crust/lithosphere is the thinnest layer of the Earth and is the layer we live on. It is made up of a variety of rocks and can reach up to 70km thick in places. It's divided into large chunks called tectonic plates. There are around 7 large and 12 small plates, which 'float' on top of the mantle beneath them. There are 2 different types of plates; continental which is under the land and oceanic under the sea. Continental plates are thick (25-70km) and light because they are made of rocks with a low density. Oceanic plates are thin (6-11km) and heavy because it is made of rocks (mostly volcanic rocks) that have a high density. The oceanic plates covers 2/3 of the Earth's surface. Mantle is the thickest layer of the Earth at 2,900km thick. It makes up nearly 80% of the volume of the Earth. It is divided into 2 layers, the upper and lower and the heat within these layers drives convection currents. The upper layer is semisolid rock called magma that flows slowly due to convection currents. It is less than 1,000°C in temperature. The lower layer is kept solid due to pressure and is between 1,000-3,500°C. If you had to describe the mantle as a whole, it is classed as a liquid. The inner core is made of liquid iron and nickel and is between 3,500-4,000°C. As the liquid metal swirls around, it induces a current that generates the Earth's magnetic field. Heat from the core powers the convection currents in the mantle. The outer core is the hottest part of the Earth reaching temperatures between 4,000-4,700°C, which are as hot as the surface of the sun. It is made of solid iron and nickel that are under so much pressure they cannot melt. It is 1,200km thick and heavy radioactive elements within the core generate the intense heat as they decay. **<u>Where does the earths heat come from?</u>**	

	Earth was hot when it formed. A lot of Earth's heat is leftover from when our planet formed, four-and-a-half billion years ago. Earth is thought to have arisen from a cloud of gas and dust in space. Solid particles, called "planetesimals" condensed out of the cloud. They're thought to have stuck together and created the early Earth. Bombarding planetesimals heated Earth to a molten state. So Earth started out with a lot of heat. Earth makes some of its own heat. Earth is cooling now – but very, very slowly. Earth is close to a steady temperature state. Over the past several billion years, it might have cooled a couple of hundred degrees. Earth keeps a nearly steady temperature, because it makes heat in its interior. In other words, Earth has been losing heat since it formed, billions of years ago. But it's producing almost as much heat as it's losing. The process by which Earth makes heat is called radioactive decay. It involves the disintegration of natural radioactive elements inside Earth – like uranium, for example. Uranium is a special kind of element because when it decays, heat is produced. It's this heat that keeps Earth from cooling off completely. Many of the rocks in Earth's crust and interior undergo this process of radioactive decay . This process produces subatomic particles that zip away, and later collide with surrounding material inside the Earth. Their energy of motion is converted to heat. Without this process of radioactive decay, there would be fewer volcanoes and earthquakes – and less building of Earth's vast mountain ranges. **Plate tectonics theory** Plate tectonics theory, convection currents and sea-floor spreading Alfred Wegener, a German meteorologist born in 1880, developed the idea of continental drift. He suggested that continents moved around the earth like giant rafts. Fellow scientists at the time thought the theory was ludicrous. He is now considered the father of the theory of plate tectonics. Although part of his theory of continental drift, that the continents ploughed through the ocean floor, has now been discounted, there is certain evidence for the breakup and movement of continents over the surface of the Earth. **Continental drift** The early evidence of continental drift claimed by Wegener includes: • the 'fit' of the coastlines of South America and Africa; • evidence for a late-Carboniferous glaciation exists in deposits in India, South America and Antarctica. These deposits must have been formed together and subsequently moved; • geology in northern Scotland closely match those found in eastern Canada, indicating that they were laid down in the same position;	

• fossil brachiopods found in some Indian limestones are comparable with similar fossils found in Australia;
• fossil remains of mesosaurus, a prehistoric reptile, are found in both southern Africa and South America;
• the plant Glossopteris is a fern that has been found in Africa, Antarctica, Australia and South America. It is used as evidence that these continents must have been joined together around 250 million years ago.

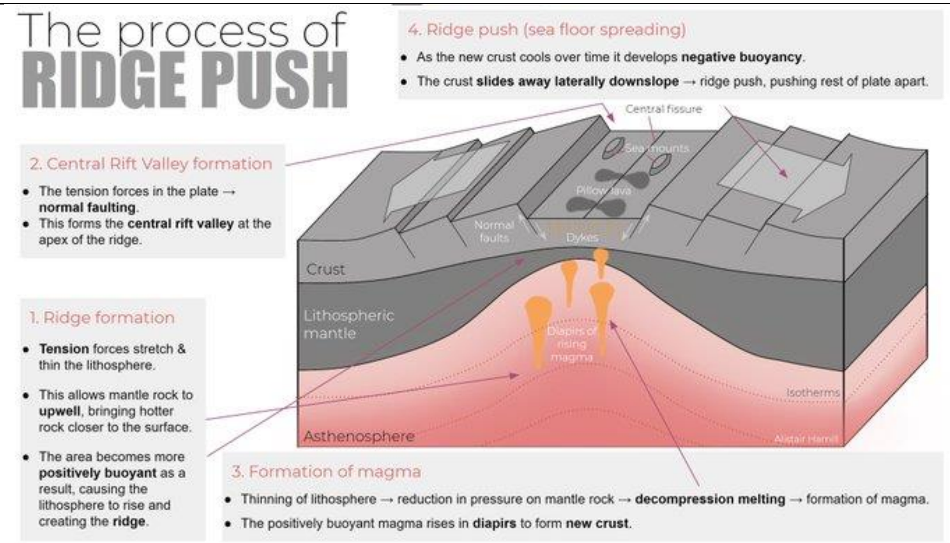
In the second half of the twentieth century, more evidence emerged that supported the theory of continental drift. This included:

• the discovery of mid-oceanic ridges discovered as the result of ocean floor mapping. A mid–ocean ridge or mid–oceanic ridge is an underwater mountain range, formed by plate tectonics. As plates move apart magma rises along the constructive plate margin forming new land along the boundary of the plates;
• **palaeomagnetism – evidence of sea-floor spreading** is gained from an examination of the polarity of the rocks that make up the ocean floor. Iron particles in lava are aligned with the Earth’s magnetic field. At regular intervals the polarity of the Earth reverses; this results in a series of magnetic stripes with the sea-floor rocks aligned alternately towards north and south poles. This striped pattern, which is mirrored exactly on either side of a mid-oceanic ridge, suggests that the ocean crust is slowly spreading away from the boundary. Also, the ocean crust gets older with distance from the mid-ocean ridge;
• the discovery of ocean trenches where large areas of the ocean floor are pulled downwards and destroyed.

Convection currents

The plates that make up the Earth’s crust are continually moving at around 2-3cm per year. The distribution of the continents today is very different to what they were millions of years ago. This is because the plates have moved as the result of convection currents in the mantle.

Tectonic plates ‘float’ on the magma beneath them in the mantle. Convection currents, that occur within the molten rock in the mantle, act like a conveyor belt for the plates. Tectonic plates move in different directions. The direction of movement and type of plate margin is determined by which way the convection currents are flowing.



<u>Plate margins</u>

Convergent (destructive) plate margins

Oceanic and continental plates may meet in one of three ways:

oceanic-continental

oceanic-oceanic

continental-continental.

Oceanic-continental

Where oceanic and continental plates meet the oceanic crust sinks, or subducts, below the less dense and lighter continental crust. Subduction leads to the formation of an ocean trench. These trenches can be up to 11,000m deep. They mark the point where the oceanic plate enters the asthenosphere. As it does this the continental crust buckles forming the trench.

As an oceanic plate converges on a continental plate the sedimentary rock formed on top of the ocean crust folds upwards along the leading edge of the continental plate. In addition to this, the continental crust also lifts and buckles and magma is injected from the asthenosphere. This process forms fold mountains of which the Andes and the Rockies are examples.

As the oceanic crust subducts the continental crust it melts. The magma rises as it is less dense than the material around it. Large intrusions of magma create uplift, further contributing to the formation of fold mountains. Volcanoes are formed where magma reaches the surface of the Earth

Oceanic-oceanic

	Where two oceanic plates converge the denser crust subducts the other. This creates a trench. As the oceanic plate descends it melts, and the magma rises forming a volcanic island chain, known as an island arc. The north-west Pacific Ring of Fire has a series of island arcs including the Aleutian Islands. Continental-continental Where two continental plates meet there is typically no subduction. Fold mountains, such as the Alps and the Himalayas form **Constructive (divergent) plate margins** Constructive plate margins involve two plates moving away from each other. Where this occurs magma rises through the asthenosphere to the surface of the Earth. This typically occurs along a mid-oceanic ridge, such as the mid-Atlantic rift that extends from the north to the south of the Atlantic ocean. Long chains of mountains form along these ridges. Due to the varying amount and rate of magma released mid-oceanic ridges vary in shape. Eruptions along constructive plate margins mainly occur underwater. Pillow lavas are formed as lava is rapidly cooled on the sea floor. In the North Atlantic the extrusion of magma has been so great it created the largest volcanic island in the world, Iceland. As magma rises the rocks above often form a dome. The lithosphere is put under great stress and eventually fractures along faults. This forms the underwater rift valleys found along mid-oceanic ridges. Rift Zones Rift zones also occur on land and help explain how continents break up. The continental crust must be thin for rifting to happen. One of the best examples is Iceland’s rift valley, þingvellir. This is where the North American Plate and the Eurasian plate are separating. A graben or sunken valley has been formed where the crust has been stretched, causing faulting. **Conservative plate margins** At conservative plate margins, tectonic plates slide past each other. There is no volcanic activity associated with conservative plates, though earthquakes can often occur. This is because plates do not pass each other smoothly; friction causes resistance. As pressure builds the crust can fracture releasing energy as earthquakes. It is possible to see the boundary between plates along a conservative margin. An example of this is the San Andreas fault in California. This is where the North American and Pacific plates slide past each other.	

Volcanoes

What is a volcano?

A volcano is an opening in the Earth's crust where magma – a mixture of red-hot liquid rock, mineral crystals, rock fragments and dissolved gases from inside the planet erupts onto the surface.

The nature of vulcanicity

Volcanic eruptions produce a wide range of landforms. These landforms are affected by the type of lava, the materials produced and how the eruption takes place. The behaviour of lava is affected by its viscosity (consistency e.g. thick, sticky, semi-fluid), which is determined by its chemical composition and temperature. Volcanoes can be classified according to the type of eruption.

The products of explosive eruptions

Explosive eruptions involve magma being violently fragmented when expelled from a volcano.

Strato-volcanoes (composite) volcanoes

Composite volcanoes, sometimes known as stratovolcanoes, are steep-sided cones formed from layers of ash and acidic lava flows. Most composite volcanoes contain complex internal networks of lava flows which contain intrusive (below ground) igneous features such as sills and dykes. The eruptions from these volcanoes may be a pyroclastic flow rather than a flow of lava. A pyroclastic flow is a superheated mixture of hot steam, ash, rock and dust. A pyroclastic flow can travel down the side of a volcano at very high speeds with temperatures over 400 degrees Celsius. Composite volcanoes can rise over 8000 feet.

When composite volcanoes erupt they are explosive and pose a threat to nearby life and property. Eruptions are explosive due to the thick, highly viscous lava that is produced by composite cone volcanoes. This viscous lava has a lot to do with why they are shaped the way they are. The thick lava cannot travel far down the slope of the volcano before it cools. Composite volcanoes are usually found at destructive plate margins. Examples of composite volcanoes include Mount Fuji (Japan), Mount St Helens (USA) and Mount Pinatubo (Philippines). Convergent plate boundaries and explosive eruptions give rise to chains of strato-volcanoes. There are 66 strato-volcanoes in the Andes that have recently erupted.

Calderas

A caldera is a volcanic crater, usually more than 2km in diameter. They form when an explosive eruption destroys the cone and the magma chamber below is emptied. Without magma providing support below a caldera is formed when the sides of the volcano collapse.

The products of effusive eruptions

An effusive eruption is a type of volcanic eruption in which lava steadily flows out of a volcano onto the ground.

Shield volcanoes
Shield volcanoes are low with gently sloping sides and are formed from layers of lava. Eruptions are typically non-explosive. Shield volcanoes produce fast flowing basic (fluid) lava that can flow for many miles. Eruptions tend to be frequent but relatively gentle. Although these eruptions destroy property, death or injury to humans rarely occurs.
Shield volcanoes are usually found at divergent (constructive) boundaries and sometimes at volcanic hotspots. Examples of shield volcanoes include Mount Kilauea and Maunaloa on Hawaii. Iceland owes its existence to effusive eruptions at a divergent margin between the North American and Eurasian plates.
Eruptions at hot spots
The chain of islands that form Hawaii lie at the centre of the Pacific Ocean, thousands of miles away from a plate margin. Hawaii was formed due to a volcanic hot spot. This is a fixed area of volcanic activity where magma rises from a mantle plume. As the Pacific Plate moves north-west over the plume huge amounts of basalt have accumulated on the ocean floor to produce the Hawaiian islands. As the plate moves away from the hot spot active volcanoes lose their source of magma and become extinct. Not all volcanoes that form at hot spots are shield volcanoes. El Tiede on Tenerife is a strato-volcano.
Are all volcanoes active?
Volcanoes are found in three states – extinct, dormant and active. An extinct volcano will never erupt again. A dormant volcano has not erupted in 10000 years. An active volcano has erupted recently and is likely to erupt again. Mount Kilauea, Hawaii, is an example of an active volcano.

Are all volcanic eruptions the same?
The simple answer is no! Volcanic eruptions are often thought of as cataclysmic explosions that produce vast quantities of lava, ash and other volcanic materials. However, volcanoes can actually erupt in a range of different ways. A volcano can erupt in a range of different ways during different eruptions and even during different stages in the same eruption.
Icelandic eruptions
Icelandic eruptions are characterised by a persistent eruption along a fissure. Large volumes of basaltic lava form large horizontal plains or plateaux. The Deccan Plateaux is an example.
Hawaiian eruptions
In Hawaiian eruptions, the lava is more basic and basaltic, with low gas pressures and low silica content. This means the lava is very runny. These eruptions are generally not explosive or destructive and do not throw huge amounts of Tephra or pyroclastic material in the air. Instead, they produce low-viscosity, low-gas-content lava that flows over large areas producing gently sloping shield

volcanoes and lava plateaus. Eruptions can form fire fountains, Lava thrust up to 50m in the air for many hours. The general eruption style is a steady lava flow from a central vent, which can produce wide lava lakes, ponds of lava forming in craters or other depressions.

Strombolian eruptions

Strombolian eruptions are named after Stromboli in Italy. The effects are impressive but not particularly dangerous. They eject short bursts of lava 15 to 90 meters in the air. The lava has a fairly high viscosity (it's quite thick due to its high silica content), so gas pressure builds up before the material can be ejected from the volcano. These regular explosions can produce impressive booming sounds, however, the eruptions are relatively small. Lava flows from Strombolian eruptions are not common though they do produce small amounts of ash.

Vulcanian Eruptions

Vulcanian eruptions involve violent gas explosions that blow out sticky plugs of lava. These fragments build up cones of ash and pumice. Lava is very viscous and solidifies rapidly. The eruption usually clears a blocked vent and releases a significant amount of ash.

Vesuvian Eruptions

Named after Mount Vesuvius, vesuvian eruptions involve very large blasts of gas that force large ash clouds into the sky. They are more violent than Vulcanian eruptions. Ash falls on the surrounding area and lava flows can also happen.

Plinian eruptions

These the most explosive and violent of volcanic eruptions. They produce huge plumes of ash and gas that typically takes the shape of a huge mushroom cloud. Plinian eruptions are also known as Vesuvian eruptions due to their similarity to the eruption of Mount Vesuvius in 79BC. In Plinian Eruptions the magma has high silica content. They are highly explosive and the AD79 eruption that buried Pompeii and Herculaneum was one of these. Plinian eruptions are started by highly viscous magma that has high gas content. As the magma emerges it depressurizes and this allows the gas to expand, propelling pyroclastic material as high as 45 km in the air, at hundreds of feet per second, up and out of the Troposphere. These eruptions can last for days and create a sustained and tall http://www.buyambienmed.com eruption plume, which drops a huge amount of tephra, fallen volcanic material, on surrounding areas. Additionally, a Plinian eruption can produce extremely fast-moving lava flows that destroy everything in their path.

1. Nuée ardente	a) A fast-moving cloudlike mass consisting of gases, hot ash, and other material ejected from an erupting volcano.

2. Lava flows	b) Are streams of molten rock that pour or ooze from an erupting vent. It is erupted during either nonexplosive activity or explosive fountains.
3. Mudflow	c) Is a form of mass wasting involving "very rapid to extremely rapid surging" of debris that has become partially or fully liquefied by the addition of significant amounts of water to the source material.
4. Pyroclastic flow	d) In a volcanic eruption, a fluidized mixture of hot rock fragments, hot gases, and entrapped air that moves at high speed in thick, gray-to-black, turbulent clouds that hug the ground. The temperature of the volcanic gases can reach about 600 to 700 °C (1,100 to 1,300 °F). The velocity of a flow often exceeds 100 km (60 miles) per hour and may attain speeds as great as 160 km (100 miles) per hour.
5. Tephra	e) Is fragmental material produced by a volcanic eruption regardless of composition, fragment size, or emplacement mechanism.

According to the activity of volcanoes, there are extinct, active, and dormant categories. Easily recognized volcanoes are active volcanoes, but dormant and extinct volcanoes are difficult and dangerous sometimes. The people living near known extinct and dormant volcanoes must always be on the lookout. Volcanoes can erupt at any time without warnings.

The constantly erupting volcanoes are active. The eruption is usually quiet but can sometimes be violent. Stromboli, which lies on an island near Italy, is a famous active volcano.

Intermittent volcanoes erupt at fairly regular time periods. Mount Asama, Mount Etna, and Hualalai are some intermittent volcanoes.

Inactive volcanoes that have not erupted for an amount of time but can't be called extinct are called DORMANT volcanoes.

Inactive volcanoes which have not erupted since the beginning of recorded history are extinct volcanoes. They will never erupt again unless they are still dormant and have been mistaken for extinct volcanoes.

Volcano Explosivity Index

Boxes not proportional – just a visual indication that ejecta volume goes up by the power of 10 for each level of the VEI

VEI	Ejecta volume	Classification	Description	Plume	Frequency	Tropospheric injection	Examples
0	< 0.00001 km^3	Hawaiian	effusive	< 100 m	constant	negligible	Kīlauea
1	> 0.001 km^3	Hawaiian / Strombolian	gentle	100–1000 m	daily	minor	Nyiragongo (2002)
2	> 0.001km^3	Strombolian / Vulcanian	explosive	1–5 km	weekly	moderate	Mount Sinabung (2010)
3	>0.01 km^3	Vulcanian / Peléan	severe	3–15 km	few months	substantial	Nevado del Ruiz (1985), Soufrière Hills (1995)
4	> 0.1 km^3	Peléan / Plinian	cataclysmic	10–25 km	≥ 1 yr	substantial	Mount Pelée (1902), Eyjafjallajökull (2010)
5	> 1 km^3	Plinian	paroxysmal	20–35 km	≥ 10 yrs	substantial	Mount St. Helens (1980)
6	> 10 km^3	Plinian / Ultra-Plinian	colossal	> 30 km	≥ 100 yrs	substantial	Krakatoa (1883), Mount Pinatubo (1991)
7	> 100 km^3	Ultra-Plinian	super-colossal	> 40 km	≥ 1,000 yrs	substantial	Tambora (1815)
8	> 1,000 km^3	Supervolcanic	mega-colossal	> 50 km	≥ 10,000 yrs	substantial	Yellowstone (640,000 BP), Toba (74,000 BP)

Glossary

Effusive: igneous rock poured out when molten and later solidified.

Tropospheric injection: Amount of gases sent into the lowest level of the atmosphere

	Volcano case study: see L11 guided reading and powerpoint and the text book L13 guided reading **<u>Volcanic eruption management strategies</u>** ***Practical Strategies*** The main Strategy for preserving lives in the event of an eruption is Public Information. 1. Public Preparation: making sure the public are prepared and know what to do before, during and after and eruption. 2. Establish evacuation centres, routes and logistics 3. Put out information on TV, radio or if need be personal contact 4. Drills and Sirens 5. Clear up teams 6. Co-ordination of emergency Services 7. Exclusion Zones 8. Hazard and risk maps and land use planning. ***Monitoring*** Record seismic activity in the area. • Short Period Earthquakes: magma fractures brittle rocks as it pushes towards the surface • Long period earthquakes: Or resonance waves caused by the pressurising of gas in the volcanoes plumbing. • Harmonic tremors: caused by the magma pushing against the rocks above. Can be felt on the surface as a buzzing or humming sensation. ***Gas emissions*** Particularly of Sulphur dioxide, will increase as a volcano moves closer to erupting. Sulphur emissions increased 10x before Pinatubo erupted in 1991. However just before the volcanoes erupt it has been observed that emissions drop as gas escape pathways are blocked by hardened magma. This increases pressure within the system and makes the eruption more explosive. Taking ground measurements is dangerous so geologists also use aerial sensors such as COSPEC (Correlation spectrometer) for measuring Sulphur dioxide. Li-COR measures CO_2 emissions. ***Ground deformation*** Rising magma can cause the ground above to swell or inflate. Geologists measure the rise and fall with tiltmetres, lasers, GPS and satellite radar. A network of seismometers is placed around the volcano and readings relayed to a computer where the earthquake patterns can be analysed. A network of tiltmetres can pick up changes in inflation and deflation of the volcanoes surface.	

Temperature changes
Infrared sensors both airborne and hand held can be used to map the heat being given off by the volcano. The Infra-red sensors on satellites can also pick out volcano hotspots although resolution is limited by the sensor and will not be as detailed as plane data.
Drainage and hydrology
Changes in the level of water in boreholes can be used to redict eruptions. Ananysis of river sediments and changes in river erosion rates can also help.
Satellite Remote Sensing
Satellites can be used to monitor volcanoes. Eruption clouds can be mapped and seperatd from normal clouds. Sulphur dioxide can be picked up using TOMS (Total Ozone Mapping Spectrometer) which is used normally for mapping Ozone. Thermal and deformation sensing can also be carried out from space.
Geomorpholgy
Historic paths of landslides, lahars, rockfalls and pyroclastic flows can be mapped to show likely routes in the future.

Earthquakes
Aftershock: a smaller earthquake that occurs after a larger earthquake.
Compression: a type of stress that squeezes rock, causing it to break or fold.
Epicentre: the point on Earth's surface directly above the focus of an earthquake
Fault: a break in Earth's crust where movement of rock occurs.
Focus: the point below Earth's surface where movement of rock produces an earthquake.
Magnitude: the measurement of the total strength or amount of energy released by an earthquake.
Mercalli scale: a measurement of an earthquake's intensity based on how much damage it causes ranges from Level I (not felt except by very few under favourable conditions) to Level XII, (causing almost total destruction.)
P (Primary) wave: the fastest moving type of seismic wave, which expands and compresses rock, like the movement of a slinky. Also known as pressure waves. Can travel through both liquids and solids.
Reverse fault: a type of fault where compression pushes rock together. Also known as a thrust fault.

Richter scale: a measurement of the magnitude of an earthquake based on the readings of a seismograph. Is a logarithmic scale ranging from 0 to 9, with each number representing a 10-fold increase in ground motion, and a 30-fold increase in energy released.

	S (Secondary) wave: the second-fastest moving type of seismic wave, which moves rock horizontally from side to side. Also known as shear waves cannot pass through liquids, and therefore cannot pass through Earth's liquid outer core. Seismic wave: a vibration that travels through Earth carrying the energy released during an earthquake. Surface waves: seismic waves that move along Earth's surface. They can have an up-and-down motion or a horizontal motion. Travel slower than P or S waves and usually cause the most damage. **<u>Measuring Earthquakes – The Mercalli Scale and Richter Scale</u>** Earthquakes can be measured in two ways – The Richter Scale and the Mercalli Scale. The Richter scale measures the magnitude of an earthquake (how powerful it is). It is measured using a machine called a seismometer which produces a seismograph. A seismometer detects the vibrations caused by seismic waves and creates graph, which scientists use to work out the magnitude of the earthquake. Seismographs are very sensitive and can detect very small tremors. Modern seismographs can cost around $30,000. Seismographs need to be maintained and can break if not maintained properly. A Richter scale is normally numbered 1-10, though there is no upper limit. It is a logarithmic scale which means, for example, that an earthquake measuring magnitude 5 is ten times more powerful than an earthquake measuring 4. By measuring accurately and giving the magnitude a score, scientist and seismologists can compare earthquakes easily. The Mercalli Scale measure the damage an earthquake causes in an area. This does not require any scientific equipment and uses people's observations. As there is no equipment required it has no costs involved in working out the level of the earthquake. Also, as it uses people's opinions, it isn't fully accurate as people may have different opinions. The Mercalli Scale is numbered 1 to 12, which 1 being the lowest. The scale looks at the damage and destruction caused by an earthquake, for example damage to houses, road surfaces, or bridges. If there is no damage, it investigates how people felt the earthquake and how many felt it. As the scale looks at damage, it can only really be used in towns and cities where there are lots of building that may have been damaged. **<u>Tsunami</u>** Tsunamis are giant sea waves generated by shallow-focus underwater earthquakes (the most common cause), volcanic eruptions, underwater debris slides and large landslides into the sea.	

To generate a tsunami, the earthquake has to cause a vertical displacement of the sea bed. This in turn displaces water upwards which generates a tsunami at the ocean surface.

Tsunamis have a very long wavelength (sometimes over 100km) and a low wave height (under 1 metre) in the open ocean, and they travel quickly at speeds of over 700km per hour (some tsunamis take less than a day to cross the Pacific Ocean) but, when reaching shallow water bordering land, increase rapidly in height.

Quite often, the first warning given to coastal populations is the wave trough in front of the tsunami which results in a reduction in sea level, known as a drawdown. Behind this comes the tsunami itself, which can reach heights in excess of 25m. The event usually consists of a number of waves, the largest not necessarily being the first. When a tsunami reaches land, its characteristics will depend upon:

- the height of the waves and the distance they have travelled
- the length of the event (at source)
- coastal physical geography, both offshore and in the coastal area.

As water depth decreases, friction between the tsunami wave and the sea bed slows the wave down. As the wave slows, wavelength dramatically decreases but wave height increases. This produces a series of huge waves, metres high. Many tsunamis have an effect at least 500-600 metres inland, depending upon the coastal geography.

Around 90% of all tsunamis are generated within the Pacific Basin, associated with the tectonic activity taking place around its edges. Most are generated at convergent plate boundaries where subduction is taking place, particularly off the Japan-Taiwan island arc (25% of all events).

See L16 for the case study

<u>Tropical storms</u>

A tropical storm is an intense low pressure weather system, that can last for days to weeks within the Tropical regions of our planet. They are tropical revolving storms because they are spun on their journey by the Coriolis force of the Earth's spin.

Tropical storms are known by many names, including hurricanes (North America), cyclones (India) and typhoons (Japan and East Asia). They all occur in a band that lies roughly between the tropics of Cancer and Capricorn and despite varying wind speeds are ferocious storms. Some storms can form just outside of the tropics, but in general the distribution (location) of these storms is controlled by the places where sea temperatures rise above 27°C and is heated to a sufficient depth.

Tropical storms are defined by their wind speeds and the potential damage they can cause, using what is known as the Saffir Simpson scale. Many tropical storms form between the tropics, some develop into tropical depressions but not many actually develop into full blown hurricanes/cyclones/typhoons. As the sea temperature increases uplift of air increases and pressure decreases. The Saffir Simpson

also accounts for the height of the storm surge, the huge waves of water that are whipped up by the storms.
The Saffir-Simpson scale for Hurricane classification

Wind speeds are used to decide what category of storm a tropical storm is, over 120Kph or 74 mile per hour is needed for a category 1 hurricane, Over 250Kph or 149 miles per hour is the worst hurricane, a category 5 which would cause extreme damage. Watch an animation of the Saffir-Simpson scale in action.

How Tropical storms form:

Tropical storms form whenever sea temperatures rise above 27 °C and can be up to 650km across. They occur where the trade winds converge and often when the ITCZ has migrated to its most Northerly extent allowing air to converge or come together at low levels. The suns heat passes through our atmosphere and warms the ocean water throughout the summer. The sea is constantly moving and heat is redistributed to deeper parts of the ocean so this takes quite some time (this is why hurricanes occur in late summer - when sea temperature is at its highest).
This causes the seas temperature to rise to 27°C and above, which encourages evaporation and the rising of air and water vapour up through the atmosphere in thermals (find out more from USA Today.com).
As these thermals rise the temperature drops (at 9.7°C per 1000m ascent or the DALR). Progressively the relative humidity rises as the air ascends (as cooler air can hold less water vapour than warmer air), eventually this causes the water vapour to condense into tiny droplets around dust and pollen (condensation nuclei). These droplets collide together to form bigger droplets and thus helps to form huge cumulonimbus clouds. Latent heat is released during condensation fuelling the storm further. Eventually these droplets will collide and coalesce with one another, become bigger and fall as rain. As a result of condensation, latent heat is released and te air cools at a slower rate, the SALR, this fuels the storm further.
Because the air has risen in the centre of this storm, an area of low atmospheric pressure exists at the surface. The Earth's atmosphere acts to balance this out as air rushes from surrounding high pressure areas to the centre of the storm along the pressure gradient. This creates the high winds in the storm, and the lower the pressure gets in the centre of the storm relative to the pressure surrounding the storm, the stronger the winds will become as the pressure gradient steepens.
The whole storm slowly migrates across oceans towards land, and because of the Earths rotation or spin (known as the Coriolis force or effect (click here to see an animation)), the whole storm starts to

spiral around a central more calm point, known as the eye. The pressures and weather are more stable in the eye, as the updrafts of air are balanced by descending cooled air.

See L19 for case studies

What are the hazards associated with tropical storms?

Strong winds-75mph at least

Storm surge-high water that sweeps inland from the sea linked to low pressure which causes a vertical uplift of water and strong winds

Coastal and river flooding-due to heavy rainfall linked to the low pressure

Landslides- 90% of landslides are due to heavy rainfall.

Saffir Simpson scale

Saffir–Simpson scale

Category	Wind speeds (for 1-minute maximum sustained winds)			
	m/s	knots (kn)	mph	km/h
Five	≥ 70 m/s	≥ 137 kn	≥ 157 mph	≥ 252 km/h
Four	58–70 m/s	113–136 kn	130–156 mph	209–251 km/h
Three	50–58 m/s	96–112 kn	111–129 mph	178–208 km/h
Two	43–49 m/s	83–95 kn	96–110 mph	154–177 km/h
One	33–42 m/s	64–82 kn	74–95 mph	119–153 km/h

How to deal with tropical storms

Preparedness

Most people living in areas at risk from tropical storms are aware of the potential dangers. This is through education and public awareness campaigns, using posters, radio and television to warn people of the dangers and provide instructions about what to do before, during and after a tropical storm event. This can involve making minor structural improvements to buildings (e.g. stronger doors and windows), preparing emergency supplies and planning evacuation routes. Property can also be insured against storm damage.

In Florida, USA, evacuation routes and cyclone shelters are clearly signposted. Individual families are encouraged to make a plan and have provisions ready in case they need to act quickly. There is no question that mass evacuation programmes have been immensely important throughout the world in saving lives.

It is now possible to use satellites and other technology such as radar to identify and track tropical storms. Computer models based on historical data enable scientists to predict the likely course or track of an individual storm. In the USA and the Caribbean a 'Hurricane Watch' is issued for those areas of land where hurricane-force winds are a serious possibility within 36 hours. This will be upgraded to a 'Hurricane Warning' when landfall is expected in the next 24 hours or less.

Adaptation

Adapting to the threat posed by tropical storms is for many people around the world the most realistic option. Tropical storms cannot be prevented so people simply have to learn to live with the threat and do what they can to minimise the risks. Clearly, to some extent adaptation can also involve elements of preparedness and mitigation.

A good example of adaptation involves land-use zoning that aims to reduce the vulnerability of people and property at the coast. Most commonly this allows only low-value land uses (e.g. recreation) to occupy the coastal strip. In parts of north-eastern Florida, coastal properties are raised above the ground on stilts and have non-residential functions on the ground floor, such as a garage or storage area (Figure **7**). This shows how people have adapted the functionality of their houses to accommodate the threat posed by storm surges. Storm surge elevation markers help to give an indication of which buildings are at risk when a storm warning is issued (Figure **8**).

Following the devastation of the Australian city of Darwin in 1974, when Cyclone Tracy destroyed 94 per cent of the houses and left 40 000 people homeless, the city authorities recognised the need to adapt to the problem of strong winds when rebuilding the city. The use of improved wind-resistant structures in building design was mandatory, which has proved to be effective in reducing losses. Regular inspection and maintenance programmes help to ensure the effectiveness of this approach.

Mitigation

Mitigation can involve a range of measures, including structural intervention, disaster aid and insurance cover.

Structural responses

It is possible to offer some protection from storm surges by soft engineering schemes (planting trees and building up beaches) or hard engineering, such as constructing sea walls (Figure **3**). There is an increasing recognition of the importance of coral reefs in acting as a buffer in reducing storm surges. It is therefore important, for several reasons, to maintain the healthy reef ecosystems that fringe many tropical coastlines (see 6.10).

In South Carolina, USA, the South Carolina Department of Insurance administers the Safe Homes Program, which provides grant money to local homeowners to make their property more resilient to hurricane and wind damage. The principle behind the initiative is that less damage will result in fewer insurance claims and lower premiums. Increasing resilience includes reinforcing gable ends, strengthening roofs and installing stronger doors and windows.

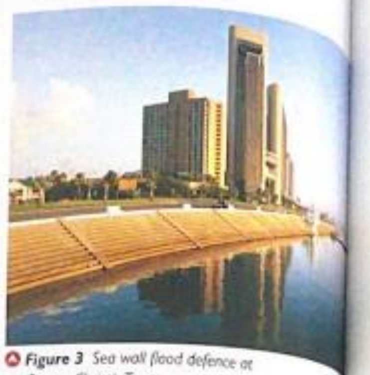


Figure 3 *Sea wall flood defence at Corpus Christi, Texas*

Disaster aid

Disaster aid can take two forms:

- immediate humanitarian relief in the form of search and rescue, food, water, medicine and shelter
- longer-term reconstructional aid that seeks to support recovery and reconstruction.

The first stage in any impending disaster is for the government to declare a state of emergency, as this often triggers federal/state support both financially and also in terms of mobilising armed forces and emergency services.

Immediately after disaster has struck, most governments seek support from the international community, particularly neighbouring countries and those with historical, political or economic links. Disaster aid can take the form of expert personnel (e.g. engineers, doctors, search and rescue), transport (e.g. helicopters) or relief supplies (e.g. food, water, shelter) (Figure **4**). Aid can also come from trading blocs such as the EU or from international bodies such as the World Bank or the United Nations. Charities and other NGOs also provide valuable support, often reflecting generous donations from members of the public.

Longer-term aid may come from a variety of sources and could take the form of either a loan to help a country rebuild or direct help, for example, involving charities working within stricken countries.

Disaster aid played an important part in both case studies (see 5.18).

Figure 4 *Médecins sans Frontières workers distributing aid following the floods in Pakistan, 2010*

Insurance

Insurance cover is widely used to mitigate the effects of tropical storms, particularly in HICs. In the USA, people living in hurricane-prone areas are encouraged to take out insurance against wind damage and to follow certain building codes and regulations, for example on windows and doors. The fact that some car insurance policies only cover damage to windscreens and not side windows can result in apparent bizarre behaviour prior to a storm as residents seek to park their cars in the direction of the oncoming storm!

There are huge social issues regarding insurance – the rich can afford the high premiums, whereas the poorest in society cannot. Many of the poorest people in New Orleans who were most severely affected by Hurricane Katrina in 2005 did not have insurance; they remained behind in the city to safeguard their property, refusing to be evacuated to safety. This serves to illustrate how behavioural responses are determined to some extent by potential economic losses (Figure **5**).

Prevention

In the past, scientists have attempted to use cloud seeding (dropping crystals into clouds to cause rain) in order to dissipate tropical storms and make them less powerful. However, this has not worked and scientists now focus on forecasting, together with mitigation and adaptation, in reducing the impacts of tropical storms.

While a tropical storm cannot be prevented as such, it is possible, to some extent, to mitigate some of its effects. For example, sea walls can be constructed to protect coastal developments from storm surges and river flood defences can help to protect property and land from flooding (Figure **6**). However, with low-return tropical storm probabilities for many coastal areas, such approaches can be seen as financially extravagant, with behavioural responses involving forecasting, evacuation and insurance being the more favoured options.

Wildfires

Causes of wildfires

There are natural and human causes of wildfires but 90% of wildfires are caused by humans.

Natural causes

- Lightning is the biggest natural cause of wildfires.
- Spontaneous heating is where leaves and branches on the ground are heated to the point at which it catches fire without a spark.
- Volcanic eruptions produce hot lava and ash which can ignite a fire. Steep slopes can then lead to the fire spreading quickly.

Human causes

- Arson where fires are started deliberately.
- Children playing with matches
- Electricity pylons falling down in high winds.
- BBQ's and campfires that have not been extinguished properly
- Broken bottles acting as a magnifying glass
- Sparks from train wheels and machinery
- Discarded cigarettes
- Slash and burn farming techniques

Effects of wildfires

Primary

- Loss of life and injury to people and animals
- Destruction of property and possessions (this is an increasing problem as more people live in the rural urban fringe)
- Loss of vegetation and crops
- Smoke

Secondary

- Homelessness
- Health problems from the inhalation of smoke
- Loss of animal habitats
- Increased soil erosion as vegetation is no longer there to bind the soil together
- Insurance premiums rise
- Loss of jobs and income for agricultural workers who lose crops or livestock
- Access to recreational areas is restricted

Preventing Wildfires

- Remove dead leaves and branches in areas prone to wildfires.
- Organise controlled burning to remove fuel.
- Educate the public to reduce the human causes of wildfires.

Stopping wildfires once they have started

- Firefighters spray the fire with water and foam
- Organise air drops of water and fire retardant chemicals from planes to put out fires in inaccessible areas
- Spray ahead of wildfires to prevent the fire spreading
- Create fire breaks by removing a line of vegetation or digging a trench to stop the fire spreading.
- Back burning is where areas ahead of the fire and deliberately burnt in a controlled way to remove the fires fuel supply