Volcanoes KS4-KS5 presentation – Teacher's Notes

Learning objectives

- Understand what volcanoes are and name some of their key features
- Understand why volcanoes erupt and the difference between effusive and explosive eruptions
- Understand the effects magma viscosity can have on lava flows and eruptions
- Understand that volcanoes usually form at plate boundaries
- Use Hawaiian hotspot to work out how fast the Pacific plate is moving

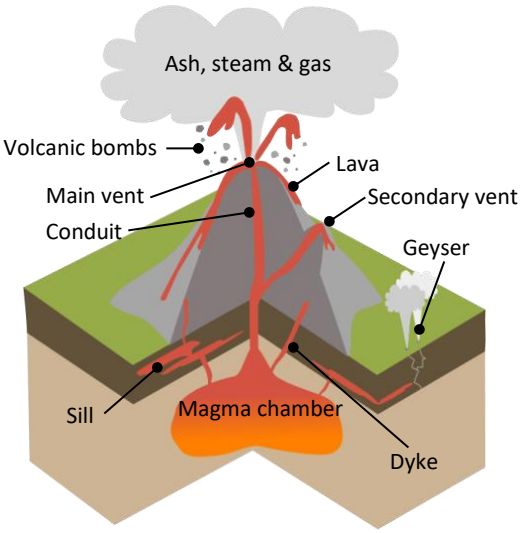
Presenter notes

Some suggested notes for each slide and information for the presenter. Questions the presenter could ask students are highlighted in bold. The Geological Society gives permission for presentations and notes to be adapted to suit the presenter's needs.

Volcanoes Overview

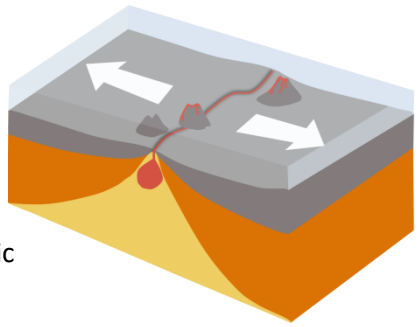
Volcanoes are openings in the Earth's rocky surface which allow hot molten rock, ash and gas to escape from below the surface. When molten rock is below the surface of the Earth it is known as magma but when it is on the surface it is called lava. The UK has many extinct volcanoes or parts of volcanoes including Helvellyn in the Lake District, Arthurs Seat in Edinburgh, Ben Nevis in Fort William and Snowdon in north Wales.

Magma deep underground collects in a magma chamber beneath a volcano. As more and more magma is added to the magma chamber, the pressure increases and causes the rock around the magma chamber to crack. The hot liquid magma, is more buoyant than the surrounding rock, so rises upwards through conduits or cracks in the crust and erupts on land through a volcanic vent. Sometimes when a volcano erupts it can blow the top off the volcano creating a bowl shaped crater. As a volcano erupts over days, weeks and even thousands of years, each eruption of lava and ash adds layers onto the volcano so that over time it grows into a huge landform.

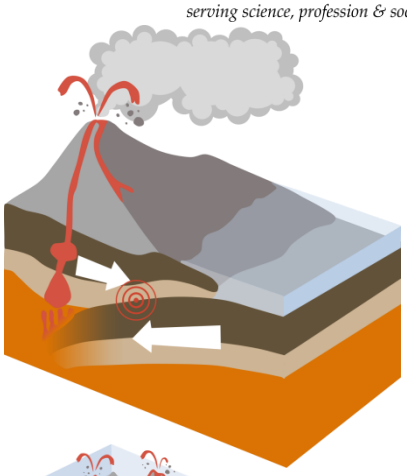


Volcanoes and plates: The Earth's crust and upper mantle are together known as the lithosphere. The lithosphere is rigid and brittle and is broken up into tectonic plates which fit together like a huge jigsaw puzzle. Most volcanoes on Earth are near plate boundaries. In fact over 75% of active volcanoes on Earth are found around the edge of the Pacific plate in a region known as the Pacific Ring of Fire.Volcanoes can occur as constructive (plates moving away from each other) and destructive (plates moving towards each other) plate boundaries as well as above hotspots.

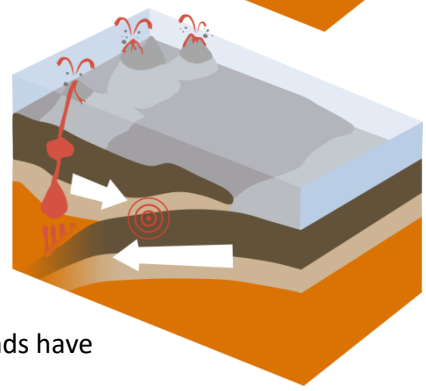
Constructive/divergent plate boundary - as plates pull apart the underlying hot mantle (asthenosphere) upwells to the surface. As it rises the pressure acting upon the mantle rocks reduces and they start to partially melt in a process known as decompression melting. This produces pockets of basaltic magma which then erupts on the surface creating new oceanic crust and underwater volcanoes e.g. the Mid Atlantic Ridge.



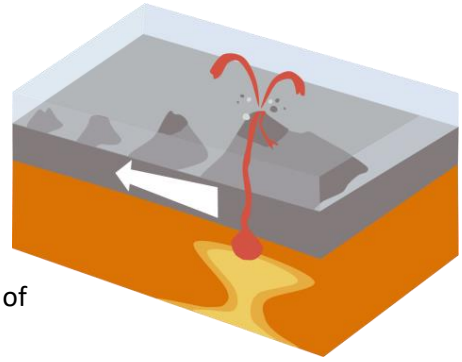
Destructive/convergent boundary (between continental and oceanic plates) - at oceanic-continental plate convergent boundaries the oceanic plate is pushed beneath or subducted the continental plate to form a subduction zone. Oceanic crust has an average composition of basalt which has a density of 2.9g/cm^3, continental crust has an average composition of granite which has a density of 2.7 g/cm^3 and so is more buoyant and will not be subducted. During subduction, hydrous minerals (minerals containing water in their structures) in the upper parts of the oceanic plate are heated and release water into the mantle. This lowers the melting point of the mantle causing it to partially melt and generate pockets of molten magma. The hot magma (up to 1000°C) rises and erupts on land typically as andesitic lava creating a continental volcanic arc like the Andes in South America and the Cascades in North America.



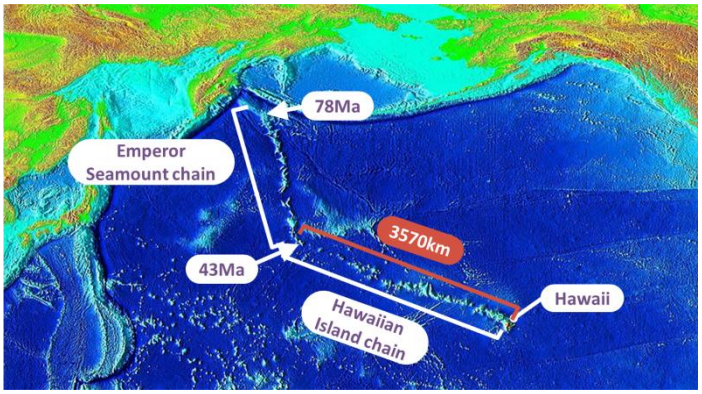
Destructive/convergent boundary (between two oceanic plates) Oceanic crust is created at a mid ocean ridges. As crust is progressively pushed away from the mid ocean ridge it cools down and becomes denser, hence older oceanic crust is denser than younger oceanic crust. When two oceanic plates meet at a convergent boundary the older plate will be subducted. Magma then forms in the same way as at continental-oceanic convergent boundaries. Volcanic arcs such as the Philippines, the Caribbean islands, the Mariana Arc and the Aleutian Islands have all been formed from oceanic-oceanic convergent boundaries.



Mantle hotspots Volcanoes (e.g. Hawaiian Islands) can form above areas of super-heated rocks in the Earth's mantle and can be far away from plate boundaries. As these hot mantle rocks rise, the pressure acting upon them reduces allowing them to partially melt to form pockets of basaltic magma. This magma then up-wells and erupts on the sea floor as a basalt volcanic seamount. As the plate gradually moves like a conveyor belt over the stationary mantle hot spot, a chain of volcanoes is formed recording the past movements of the plate.



You can use the Hawaiian hotspot to work out the speed of the Pacific plate – the oldest seamount (extinct) in the Hawaiian chain is 43 million years old and is 3570km away from Hawaii (as Hawaii has active volcanoes we assume this is the location of the hotspot).
Plate speed = Distance/time
3570 / 43,000,000 = 0.0000872093 km year^{-1}
0.0000872093*100000 = 8.72 cm year^{-1}



Explosive and effusive eruptions: Volcanoes can erupt effusively (gently) or explosively. In effusive eruptions lava can spray up as a fountain (Strombolian eruption - named after the Italian volcano Stromboli) or flow gently from the volcano as a lava flow e.g. in Hawaii. The lava in effusive eruptions is usually basaltic in composition (i.e. will form the igneous rock basalt when it solidifies). In explosive eruptions the lava is usually andesite or rhyolite. Explosive eruptions often cause huge ash columns and pyroclastic flows - flows of hot gas and ash (up to 800°C) that race down the side of a volcano at speeds of up to 10ms^{-1} (e.g. Mount St Helens in Washington, USA).

Shield and composite volcanoes: There are two main types of volcano – shield volcanoes and composite/ stratovolcanoes. Shield volcanoes form from effusive eruptions because the low viscosity lava can travel a long way before it solidifies into rock - creates wide, sloping volcanoes in the shape of a shield e.g. Mauna Loa in Hawaii, Olympus Mons on Mars. Composite/stratovolcanoes are formed from layers of alternating lava and ash, usually at destructive plate boundaries from explosive eruptions of andesitic or rhyolitic lave. The more viscous lava cannot spread out very far before it solidifies so forms cone-shaped volcanoes with steep sides

Lava type	**Basalt**	**Andesite**	**Rhyolite**
SiO_2 content	45-55%	55-65%	> 65%
Temperature	1000 - 1200^{o}C	800 - 1000^{o}C	650 - 800^{o}C.
Volatile content	Low	Medium	High
Viscosity	Low	Medium	High

Magma and lava viscosity: The nature of volcanic eruptions and type of volcano produced is highly dependent on magma viscosity - controlled by magma composition (the amount of silica, SiO_2), temperature, volatiles (dissolved gases) and amount of crystallization.

- Magmas rich in SiO_2 are typically formed at destructive plate boundaries by partial melting of crustal rocks which are richer in silica than mantle rocks. Such magmas erupt as andesite and rhyolite lavas. The higher silica content makes these magmas highly viscous, so when eruption occurs it is usually explosive (e.g. Mt St Helens).
- Low- SiO_2 magmas are typically formed by partial melting of mantle rocks beneath mid-ocean ridges or above mantle hotspots like in Hawaii. These magmas erupt as basalts and the lower silica content makes them far less viscous so the eruptions are generally effusive.
- Magma temperatures reflect the melting points of their mineral components. Magmas formed by partial melting of mantle rocks are much hotter than magmas formed from melting crustal rocks. Some Hawaiian basalts are over 1200°C decreasing their viscosity, whereas some rhyolites (melting of crustal rocks) may reach the surface at temperatures of less than 800°C, and so have much higher viscosity.
- The amount of dissolved gases in the magma can also affect its viscosity, but in a more ambiguous way. More silica-rich magmas tend to have more dissolved volatiles but as they form bubbles these gas bubbles can actually reduce the viscosity of the magma.
- Some magmas have already begun to crystallize by the time they reach the surface. This applies particularly to the cooler, more viscous magmas typical of destructive plate margins. A crystal mush will increase viscosity.

Lava types:

- Pahoehoe, pronounced 'pah-hoey-hoey', forms from slowly flowing lava and has a smooth or ropey surface when it hardens into rock, pahoehoe lava is always low viscosity and therefore is usually basaltic.
- 'A'a, pronounced 'ah-ah', forms from fast flowing lava and has a rough, rubbly surface with jagged blocks when it hardens into rock. 'A'a lava can be basaltic but it can also be andesitic or rhyolitic.
- Hexagonal columnar joints such as those seen in the Giant's Causeway and on the Isle of Mull can form in the center of thick lava flows. Parallel joints form in the basalt as the lava sheet cools and contracts.
- Pillow lava forms when lava interacts with sea water – this happen when volcanoes erupt underwater for example at mid ocean ridges, or when lava flows from land into the sea, which sometimes happens in Hawaii. Pillow lavas are characteristically pillow shaped. Each 'pillow' often has a chilled margin – a very fine-grained or glassy outer part of the pillow which cooled very rapidly in cold seawater. Pillow lavas are extremely common on Earth as they form the uppermost part of all oceanic crust.

Useful video links (links are contained within the PowerPoint presentation)

- National Geographic video on Volcano Lava (1min 11secs) https://www.youtube.com/watch?v=xExdEXOaA9A
- Effusive eruption in Hawaii (recommend to watch for about 1 minute) https://www.youtube.com/watch?v=vt3eiaduSnw
- Explosive eruption from Eyjafjalljokull, Iceland (recommend to start at 1:30) https://www.youtube.com/watch?v=e-TMtRh8AIs**)**
- Nyriagongo lava lake https://www.youtube.com/watch?v=_2th8dY03Wo

Other resources:

Volcanoes factsheet: https://www.geolsoc.org.uk/factsheets

Lava flow activity: https://www.geolsoc.org.uk/Education-and-Careers/Resources/Activity-Sheets-And-Presentations

Build a volcano activity (aimed at Key Stage 2/3 but could be a fun intro to volcanoes or homework task): https://www.geolsoc.org.uk/Education-and-Careers/Resources/Activity-Sheets-And-Presentations

What is a geothermal gradient? Presentation (A-level Geology content may be useful for higher level student science clubs – or extra information for those interested in pursuing geology at university): https://www.geolsoc.org.uk/Education-and-Careers/Resources/Activity-Sheets-And-Presentations