Volcanoes, Frankenstein, and The Scream

Behaviour of Volcanoes

Not all volcanoes are alike.

The shapes and behaviour of volcanoes largely relate to the composition of magma that form volcanic materials.

In general:

Mafic magmas have low viscosity (i.e. are “runny”) due to low silica content (about 50%) and higher T and have a relatively low volatile content--associated volcanoes tend to erupt relatively gently.

Intermediate to felsic magmas have high viscosity (i.e. are “stiff and gooey”) due to high silica content (about 60-70%) and generally lower T and have high volatile content--associated volcanoes tend to erupt explosively.

Distribution of Volcanoes

As with earthquakes, volcanoes are not randomly distributed over Earth’s surface.

Most occur at divergent and convergent plate boundaries.

Exceptions are intraplate volcanoes, which do occur within plates (due to magma generation associated with stationary mantle plumes).

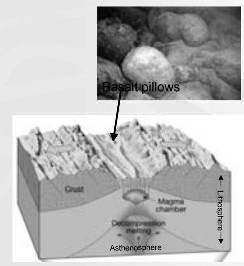
Volcanism at Divergent Boundaries

The greatest volume of volcanic rock is produced along the oceanic ridges at divergent boundaries.

Lithosphere pulls apart and mafic magma is generated by decompression melting.

Large volumes of pillow basalt are extruded underwater (pillow shapes result from rapid exterior quenching of lava bodies).

Eruptions are gentle due to low viscosity and low volatile content.

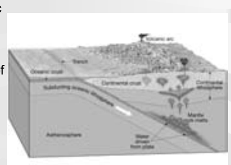


Volcanism at Convergent Boundaries

In convergent settings, a water-laden oceanic plate is subducted beneath another plate (which can be oceanic or continental).

As the plate descends, it is heated, and releases the water in the form of vapour.

Water vapour lowers the melting point of rock in the asthenosphere, allowing it to melt into magma. Silica-rich minerals melt first.



The resulting intermediate to felsic magma is viscous and retains a high volatile content (gasses can’t easily escape through flow as in mafic magmas). Eruptions tend to be explosive (gas pressure builds up until there is a catastrophic release at the threshold beyond which the magma and any solidified rock surrounding it is unable to contain the large volume of volatiles).

Volcanism at Convergent Boundaries: Continental Arcs

In cases where one slab of oceanic lithosphere is subducted under a slab of continental lithosphere, a string volcanoes is produced near the edge of the overriding continent.

This is called an continental volcanic arc.

Continental arcs are best developed along the western edge of North and South America (e.g the Andes). Mt. St. Helens is but one volcano in the Cascade (Range) arc of North America.

Magmas in continental arcs have an intermediate (andesitic) to felsic (rhyolitic) composition (magma derived from descending plate, upper mantle and contiental lithosphere.

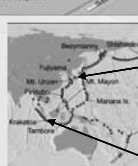
Volcanism at Convergent Boundaries: Island Arcs

In cases where one slab of oceanic lithosphere is subducted under another slab of oceanic lithosphere, an arc-shaped string of volcanoes is produced.

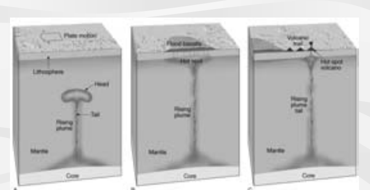
This is called a island volcanic arc. The arcuate shape mimics the curved nature of most subduction zones (in plan view--generally concave toward continent).

Island arcs occur abundantly in the western Pacific (the islands of Japan and Indonesia are good examples of island arc volcanoes).

Magmas in island arcs most commonly have an intermediate (andesitic) composition--material derived from the descending plate as well as the upper mantle.



Intraplate Volcanoes

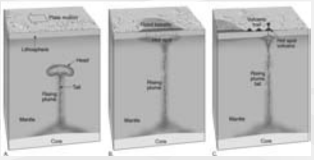


Intraplate volcanoes do not follow the same rules as plate boundary volcanoes (i.e., they do not follow plate boundaries).

These are associated with stationary plumes of heat in the mantle that dome the lithosphere and produce magma by decompression.

This process accounts for the formation of triple junctions within continental plates as well as chains of volcanic seamounts and island on single oceanic plates.

Intraplate Volcanoes



Being mantle-derived, the magma produced is mafic; eruptions tend to be gentle.

The initial eruption can extrude huge amounts of lava, forming flood basalt deposits (multiple point sources of extrusion). After the head of the plume is dispersed, the tail of the plume continues to rise, forming a hot spot (single point source of extrusion).

As the plate moves over the hot spot, a string of volcanic islands is produced. The Hawaiian Islands were formed in this way.

Common Types of Volcanoes

Volcanoes occur in many shapes and sizes, but the most common types are:

Shield volcanoes
Stratovolcanoes
Cinder cones

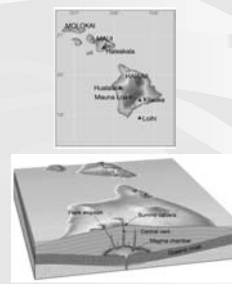
Shield volcanoes

Shield volcanoes are large, broad and slightly dome-shaped.

The low vertical profile of a shield volcano reflects the low viscosity and highly fluid nature of the basaltic lava (like making a mound out of molasses).

Large volumes of lava are erupted (sometimes in fountains) but eruptions pose little danger to people with an average or higher I.Q.

Mauna Loa, the active hotspot volcano in Hawaii is a classic example of a shield volcano. These volcanoes produce the most voluminous (Mauna Loa) and highest (from base to summit; Mauna Kea) mountains on Earth.



Stratovolcanoes

Stratovolcanoes are the type that most people visualize when they think of volcanoes (i.e., they have the "classic" volcano profile)

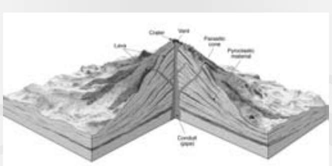
These are also known as "composite volcanoes" or "composite cones" due to the fact that they are comprised by numerous layers of lava, ash etc. (one on top of another) which represent different eruption events which contributed to the volcano's accretion.

These are the principal volcanoes associated with convergent boundaries (both island arcs and continental arcs). Most are andesitic in composition.

Mt. St. Helens (Washington, U.S.A)

Fujiyama (Japan)

Stratovolcanoes



Stratovolcanoes consist of of alternating (interbedded) lava flows and layers of pyroclastic debris which reflect relatively gradual and calm, and more catastrophic and violent phases of volcanic development, respectively.

The moderate to high viscosity of the lava, coupled with the ability of pyroclastic debris to form moderate slopes (relatively high angle of repose), permits the volcano to produce a well-defined cone shape.

Cinder Cones

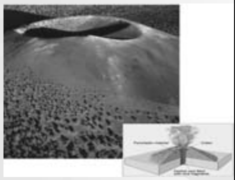
Cinder cones are very small volcanic cones that generally develop at small volcanic vents (usually) on the flanks of a larger volcano (either a shield volcano or a stratovolcano).

These are often found in clusters.

Composed mostly of pyroclastic cinders (pea-sized blobs of lava) cooled in midair. Usually there is comparatively little associated evidence of lava flows.

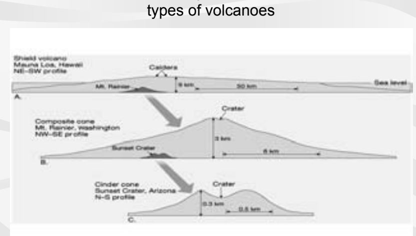
Cinders can accumulate to form relatively steep-sided cones. The longer the eruption the higher the cone will tend to be.

Cinder cones rarely exceed 250m in height and 500m in diameter.



Sunset Crater – a cinder cone near Flagstaff, Arizona

A relative size comparison of the three main types of volcanoes



Just to give you an idea of scale – note how immense a shield volcano is (but admittedly, most of Mauna Loa is underwater)

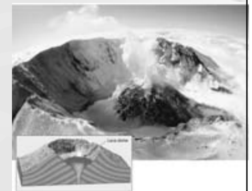
Violent Volcanic Activity

As mentioned before, volcanoes associated with subduction tend to erupt in the most violent manner.

This is a function of both the high viscosity of intermediate to felsic magma and high volatile content (the latter includes water vapour--recall that lots of water is involved in dehydration melting).

The vent and neck of a volcano can become plugged with rock fragments, pyroclastic debris and lava that have accumulated since the last eruption.

As the pressure builds below this "stopper," a lava dome can develop.



Lava dome (Mount St. Helens)

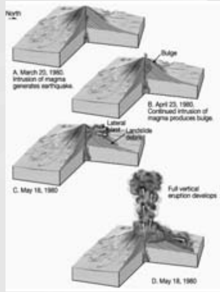
Violent Volcanic Activity

When magma resumes its ascent, along with expanding the gases, the “stopper” can rupture.

Rupture leads to a sudden release in pressure, allowing volatiles (gases) to be suddenly released.

Material surrounding the vent is pulverized and the high-viscosity lava is violently splattered into the air, generating huge amounts of airborne pyroclastic debris.

In the case of the 1980 Mt. St. Helens eruption, the rupture occurred on the side of the volcano (a lateral blast). Generally, the pressure will be relased at the weakest point in the structure.



Violent Volcanic Activity: Pyroclastic Flows

Gas charged, hot pyroclastic debris generated during a volcanic explosion can travel down the slope of a volcano a high speeds (up to 200 km/hr)--minimal drag and frictional resistance.

These form glowing pyroclastic flows (also known as “glowing avalanches”).

Meltwater from snow a the volcano’s summit can mix with loose ash to produce destructive mudflows (known as lahars).

The finest grained pyroclastic material (fine ash) is injected into the atmosphere (may take months to years to fully settle out).

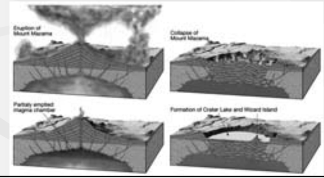
Pyroclastic flow generated during 1980 Mt. St. Helens eruption

Violent Volcanic Activity: Calderas

Even more devastating are eruptions that are so violent that the top of the volcano caves in.

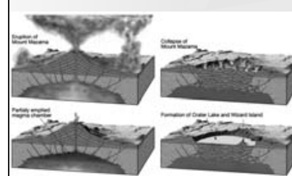
Huge amounts of pyroclastic debris and gases are released through ring fractures surrounding the summit.

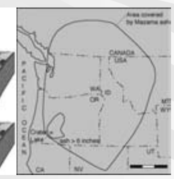
The crater produced by such collapse is called a caldera. Calderas may also form in a non-violent manner as a result of the evacuation of the magma chamber following a large eruption and resultant failure of the roof of the chamber due to lack of supporting magma pressure.



One of the best-known calderas is Crater Lake (Oregon), which was formed during the last eruption Mt. Mazama, nearly 7,000 years ago.

Associated with the formation of this relatively small caldera (about 10 km in diameter) was the deposition of an ash layer that covered a substantial area of the western U.S. and Canada.





Volcanoes and the Atmosphere

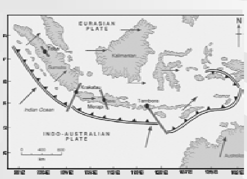
Explosive eruptions emit huge quantities of gases and fine-grained debris (particulates) into the atmosphere which filter out (absorb) and reflect a portion of the incoming solar radiation.

Examples of volcanism known to have dramatically affected climate (all located in Indonesia):

Krakatau, Indonesia – 1883

Mount Tambora, Indonesia – 1815

Toba, Indonesia – 73,500 B.C.



As well, you may remember the effect of the eruption of Mt. Pinatubo (Philippines) in 1991 on the weather during the following year. The summer of 1992 was among the coolest and wettest in recent years.

Explosion of Toba (73,500 B.C.)

Thought to have dwarfed even Tambora and Krakatau was the explosion of Toba in approximately 73,500 B.C.

This is believed to have been the highest magnitude volcanic explosion in the past 2 million years.

Evidence supporting this explosive event includes an enormous caldera 100 km in diameter, and an ash layer with a thickness of 15 cm at distances over 1000 km away from the crater!!!!

Based on current estimates, a huge volume of volcanic ash, equivalent to 2,800 km^2 of solid rock was injected up to 30 km into the atmosphere.

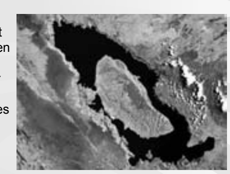
Toba caldera

Toba: Too Close For Comfort !

Computer models of atmosphere response to the eruption suggest that the ash and aerosols would have been of sufficient volume to drive tropical temperatures to the freezing point for large portions of the year and to produce abnormally cool temperatures for as long as a decade (3-5 degree average drop in global temperature).

Such temperatures would have been detrimental to any humans, and it has been speculated that humans may have ever teetered on the edge of extinction!

Toba Catastrophe Theory: Entire world human population reduced to 10,000 or fewer individuals.



Aerosols, particulates and climate

A major contribution to the climatic effect of explosive volcanic eruptions is the major release of aerosols (solid or liquid particles suspended in air), particularly sulphate (sulphur dioxide) aerosols, into the upper atmosphere. These tiny liquid particles increase the albedo of the Earth by reflecting sunlight, and thus keep some solar energy from reaching Earth's surface.

These may also contribute to greater precipitation rates as a result of the potential action as cloud condensation nuclei.

Other particulates (e.g. fine ash particles) may also have a similar overall effect.

The biggest eruption recorded in historical times was that of the Indonesian volcano Tambora (island of Sumbawa, Indonesia) in 1815.

The eruption blew 100 cubic km of ash into the atmosphere (blocking 10% of incoming sunlight), lowering global temperatures (up to 5 degrees) and causing nasty weather everywhere.

Tambora and Frankenstein

The year after the eruption (1816) was so cold in the US that it was jokingly? (maybe not) known as "Eighteen Hundred and Froze to Death."

With the lack of sunlight, many crops failed and people were starving. Snow fell in June in several regions of North America and elsewhere.

The same year was called "the year without a summer" in Europe.

The bad weather forced Lord Byron, Dr. John Polidori, and Mary and Percy Shelley to spend much of their Swiss vacation indoors. They challenged each other to write ghost stories, and Mary came up with *Frankenstein*.

The Scream

Volcanism can be tied to one of the most famous icons of modern angst, The Scream, by Norwegian artist Edvard Munch.

Munch's art (including The Scream) is strongly infused with a sense of confusion and despair, in part influenced by the various diseases and disorders that afflicted his family (including himself).

Munch executed four paintings and one lithograph of The Scream (Skrik).

The Scream (1895)
lithograph

Munch described how the painting was inspired by a brilliant sunset.

In one version of a prose poem written to accompany "The Scream," Munch recollected:

"I was walking along the road with two friends - then the Sun set - all at once the sky became blood red - and I felt overcome with melancholy. I stood still and leaned against the railing, dead tired - clouds like blood and tongues of fire hung above the blue-black fjord and the city. My friends went on, and I stood alone, trembling with anxiety. I felt a great, unending scream piercing through nature."

The Scream (1893)
(tempera on cardboard)
This is the version that was stolen from the Munch Museum (Oslo), August 22, 2004

Krakatau (1883)

Significantly, the volcano Krakatau exploded on August 27, 1883, at least roughly corresponding to the time Munch is believed to have witnessed the unusually fiery sunset..

The island of Krakatau was obliterated by the explosion, and tsunami travelled thousands of kilometres across the ocean, killing a total of at least 40,000 people. The sound of the explosion was heard 3,000 miles away.

Barometers recorded shock waves from the explosion traversing the planet seven times. And a thick pall of ash and dust rose skyward, eventually encircling the globe.

Sunlight reflecting off particles in the atmosphere tinges sunsets redder than normal (shorter wavelengths of visible light are absorbed or reflected/scattered, leaving only the red [long wave lengths] to pass through) – in the same way, smoke from wildfires can produce such spectacular sunsets.

After Krakatau exploded, skywatchers began reporting crimson skies appearing ever farther north as the ash and dust spread out.

The same phenomenon was noted after the eruption of Mt. Pinatubo in 1991.

View from the space shuttle *Endeavour* of a sunset behind volcanic dust in the Earth's atmosphere, still visible over a year after the eruption of Mount Pinatubo.

Norwegian records show that the lurid Krakatau sunsets first appeared over Oslo in late November 1883 and lasted until mid-February 1884.

The intensity of the sunset sometime during this period obviously left an indelible mark on Munch's psyche. Other paintings such as "Angst" show the same sunset.

Angst (1894)
Oil on canvas

Other artists influenced by Krakatau eruption

British artist William Ashcroft created more than 500 watercolors of Krakatau skies, sometimes generating one every few minutes.

Krakatau (Ashcroft, 1883)

Alfred Tennyson might have also been thinking of Krakatau when he penned these lines in "St. Telemachus" (from, Tennyson's last published volume, *The Death of Oenone, Akbar's Dream, and Other Poems*, 1892). :

"Had the fierce ashes of some fiery peak
Been hurl'd so high they ranged about the globe?
For day by day, thro' many a blood-red eve
… The wrathful sunset glared."

END OF LECTURE