

# VOLCANOES

What is a volcano?

- ☐ A place on the earth's surface (or any other planet) where molten rock and gases are erupted.
- ☐ A hill or mountain built up by the eruption of molten rock.

There are, however, many kinds of volcanoes. A volcano does not have to be a beautiful snow-capped conical peak. It can be a hole in the ground, or a crack in the earth's surface

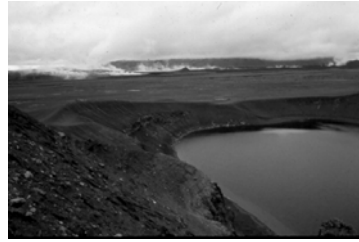


This is what we tend to think of when we think of volcanoes – beautiful, snow-capped, conical peaks. In this case Mount St. Helens prior to its 1980 eruption.

## Holes in the Ground!



Zuni Maar, New Mexico



Vitti, an explosion crater that erupted in Iceland in 1720 AD.

Maars and explosion craters are produced when hot magma (usually basalt) reacts violently with shallow water, or water-soaked ground. These types of eruptions are known as phreatomagmatic

## Cracks in the ground (fissure eruptions)



Lava and steam erupting from cracks at Krafla, Iceland in 1981

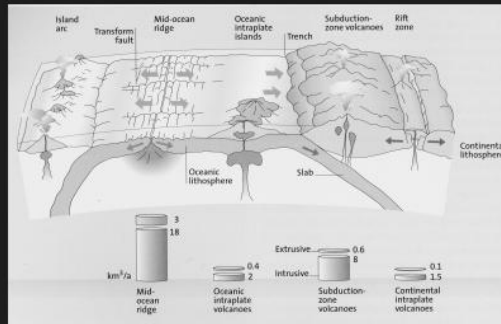


Lava flows from cracks in the Snake River Plain, Idaho.

# Where do volcanoes occur?

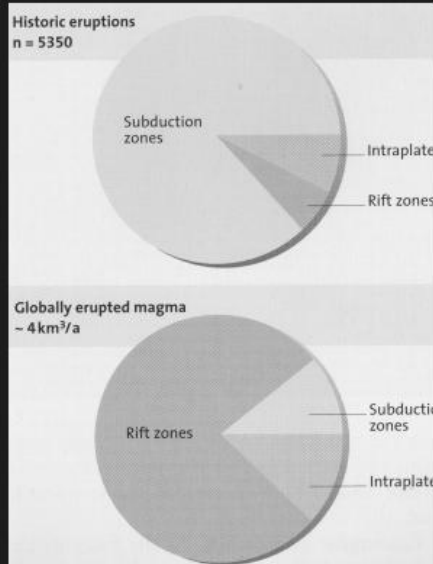
## PLATE MARGINS

- Spreading Margins
  - Mid-Ocean Ridges
  - Rifting Continents
- Converging Margins
  - Island Arcs
  - Continental margins



## PLATE INTERIORS

- Oceanic Plates
- Continental Plates



Most historically observed eruptions are associated with subduction zones.

However of the 4 km³ of magma estimated to erupt annually, the vast majority is associated with rift zones (mid-ocean ridges)

## Some Volcano Facts

The total number of recognizable volcanoes is about 10,000

**ACTIVE** – volcanoes known to have erupted during historical times.  
Total Number = 529

**DORMANT** – volcanoes that have not erupted during historical times, but will probably erupt again.  
Total Number = 1,340

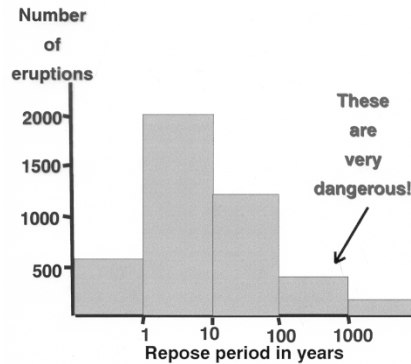
**EXTINCT** – volcanoes that are unlikely to erupt again.

more volcano facts.....

- ☐ About 500 volcanoes are currently active.
- ☐ Typically there are about 5 – 10 volcanoes erupting every month (about 50/year).
- ☐ About 262,000 people have been killed by volcanoes since 1600A.D. (this averages out at one person per year per volcano!).

## Repose Period

This is the time interval between successive eruptions.  
It can range from minutes to thousands of years!

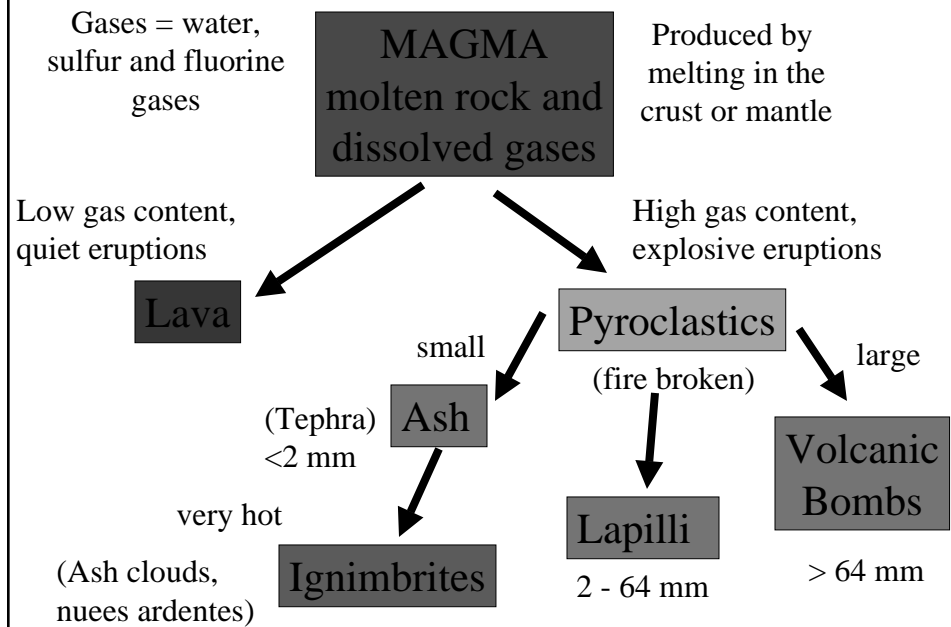


In general the longer the repose period the more explosive and dangerous the next eruption.

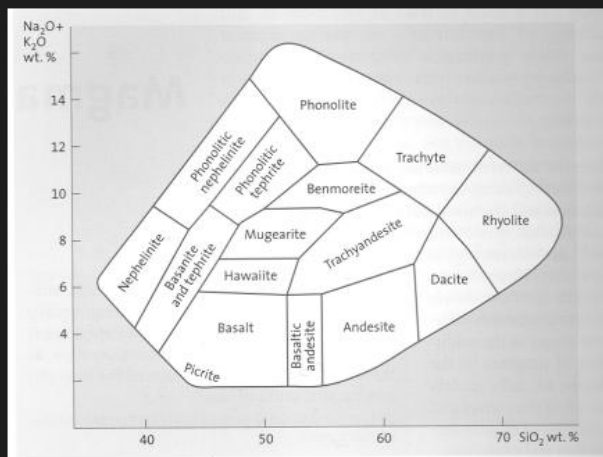
## The Major Killers

Year	Volcano	Deaths	Cause
1783	Laki, Iceland	9,340	(mostly starvation)
1815	Tambora, Indonesia	92,000	(80,000 starvation)
1883	Krakatao, Indonesia	36,000	(mostly tsunami)
1902	Mt. Pelee, Martinique	29,000	(ash flows)
1985	Nevada del Ruiz Colombia	22,000	(mud flows)

## A Simple Guide to Volcanic Rocks



## Chemical Classification of Volcanic Rocks



Tholeiitic Lavas  
Alkalic Lavas

Total alkali <  $\text{SiO}_2 \times 0.37 - 14.43$   
Total alkali >  $\text{SiO}_2 \times 0.37 - 14.43$

# Volcanic Eruptions

Two types of descriptive classifications are in common usage:-

- Morphology and Nature of the Vents
  - Fissure Eruptions
  - Central Vent Eruptions
- Style of Eruptions
  - Hawaiian
  - Surtseyan
  - Strombolian
  - Vulcanian
  - Plinian
  - Ultra-Plinian

## Central Vent Eruptions

- Monogenetic Volcanoes
  - Cinder Cones
  - Maars and Tuff Cones
- Polygenetic Volcanoes
  - Simple Stratovolcanoes
  - Compound Stratovolcanoes
  - Shield Volcanoes

## Fissure Eruptions

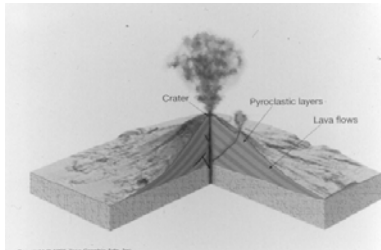
- Icelandic (Mid-Ocean Ridge)
- Plateau (Flood) Basalts
- Rhyolite and Ignimbrite Flows

# Central Vent Volcanoes

## Polygenetic Volcanoes

Volcanoes that have a long eruptive history (many thousands of years) with eruptions from a summit crater or along the flanks of the volcano. Recent studies show that there may be multiple volcanoes, with periods of dormancy and erosion, at the same site

## Stratovolcanoes.



Called stratovolcanoes because the cones are built up of layers (strata) of lava and volcanic ash. Here are a couple of other stratovolcanoes. The composition can range from basalt to rhyolite but is often andesitic



Mount Hood, Cascades



Mount Shasta, Cascades  
(also a composite volcano)





Crater Lake,  
Oregon

Crater Lake is what is now left of a large stratovolcano that blew itself to bits 6,845 years ago.

## Shield Volcanoes



Snow-covered Mauna Loa Volcano, Hawaii. The world's largest volcano, rising 13,690 ft above sea level and 33,000 ft from the ocean floor.



The summit crater (or caldera) of Mauna Loa



Mauna Kea Volcano, Hawaii



The summit crater (caldera) of Kilauea Volcano, Hawaii

Unlike stratovolcanoes that are composed of viscous lavas and ash, shield volcanoes are made of fluid basalt lavas flows, that flow much further, thus giving them their characteristic shield-like shape.

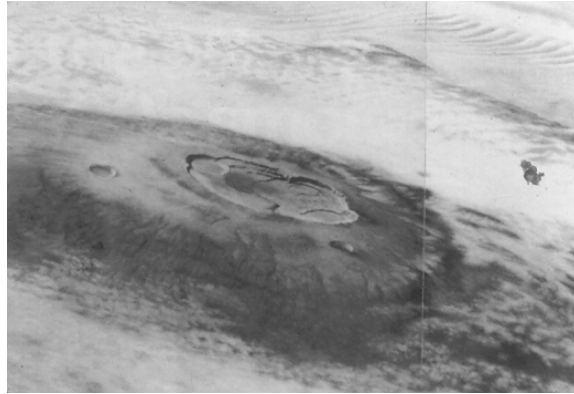


Newberry Volcano, a shield volcano in Oregon.



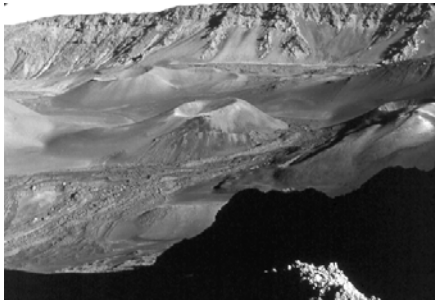
From the summit you can see that it has a large crater complete with lava flows and cinder cones.

## The mother of all volcanoes!

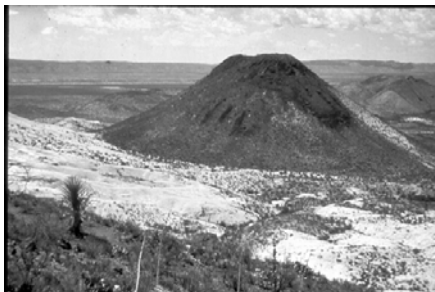


This is Olympus Mons, a giant shield volcano on Mars  
It is believed to be the largest volcano in the solar system.  
(Note the entire island of Hawaii would fit in its caldera)

## Cinder Cones



Cinder cones, Haleakala  
volcano, Hawaii



Ojo de Agua, Mexico

These volcanoes are often  
referred to as monogenetic  
volcanoes. This is because,  
unlike stratovolcanoes they  
usually only erupt once.

## more cinder cones



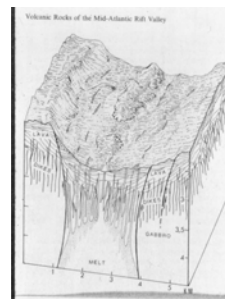
Surtsey Volcano, Iceland,  
erupting out of the sea  
in 1963.



Paricutin Volcano, Mexico,  
erupted out of a corn field  
in 1943.

## Fissure Eruptions

### ICELANDIC TYPE (MORB)



## Plateau (flood) Basalts (Large Igneous Provinces)



Lava erupting from cracks (fissure eruptions) can produce huge thick piles of lava, such as these here in eastern Iceland and the Columbia River Basalts in the N.W. U.S.A..

### Examples of Flood Basalts

❑ Parana Basalts	750,000 km <sup>2</sup>
❑ Deccan Basalts	>400, 000 km <sup>2</sup>
❑ Columbia River Basalts	220,000 km <sup>2</sup>

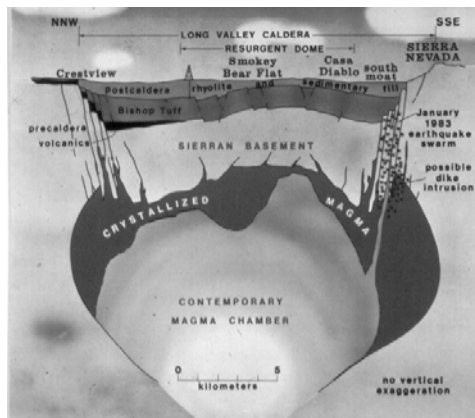
A single flow (Roza) in the Columbia River Basalts has an estimated volume of about 700 km<sup>3</sup>

The only historical example of this type of eruption, the Laki eruption (1783) in Iceland, is of a much more modest size. About 12 km<sup>3</sup> from a fissure 25 km in length

## Rhyolite and Ignimbrite Flows



Huge rhyolite and ignimbrite flows are erupted from circular fissures associated with caldera collapse. Long Valley Caldera (30 x 15 km) formed by collapse about 760,000 years ago, following a gigantic explosive eruption. The last eruption here was 600 years ago.



A sketch of what the Long Valley caldera may look like at depth.

## Some Examples

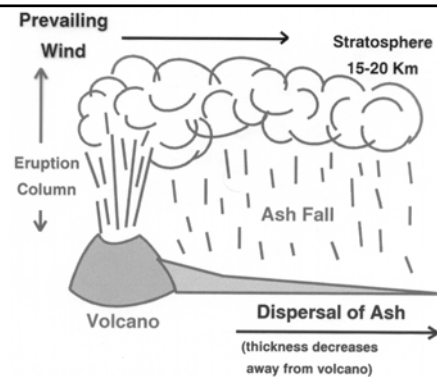
❑ Tambora, Indonesia (1815)	150 km <sup>3</sup>
❑ Bandelier Tuff, New Mexico	200 km <sup>3</sup>
❑ Bishops Tuff, Long Valley (700 ka)	500 km <sup>3</sup>
❑ Yellowstone,	2500 km <sup>3</sup>

## Style of Eruptions

Eruption types are based on the eruption characteristics of a well-known volcano.

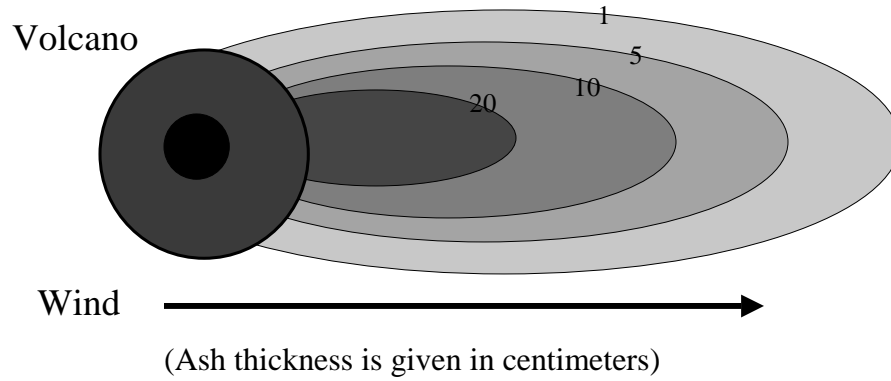
There are five such types:-

- ☐ Hawaiian
- ☐ Surtseyan
- ☐ Strombolian
- ☐ Vulcanian
- ☐ Plinian (Krakatoan)

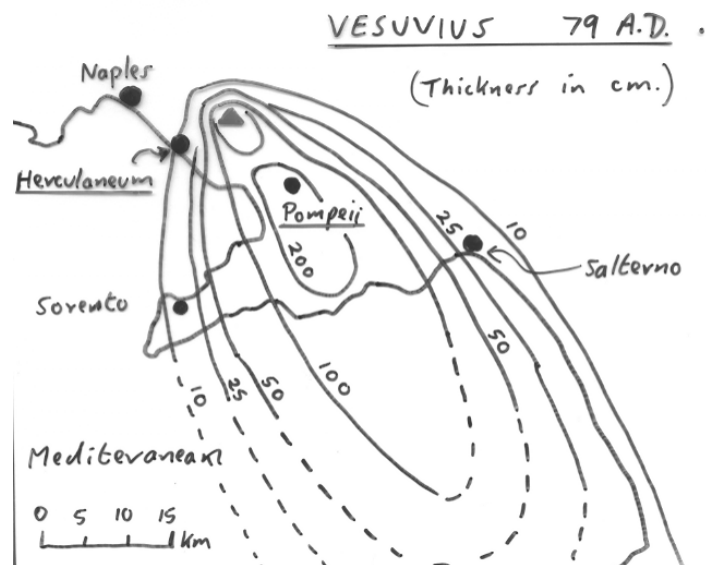


- As pressure reduces, dissolved gases in the magma expand and explosively fragment the magma.
- This mixture of gas and magma blasts out of the volcano at high speed (up to 700 m/sec), producing an expanding eruption column.
- The eruption column can extend up into the stratosphere.
- The ash then falls to the ground, blanketing large areas with thick ash deposits.

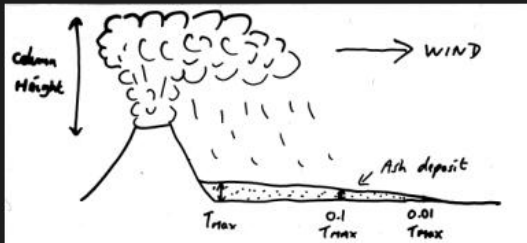
**Isopach Maps** – are contour maps that show the thickness of the volcanic ash deposits.



$$\begin{aligned} T_{\max} &= 20 \text{ cm} \\ 0.1 T_{\max} &= 2 \text{ cm} \\ 0.01 T_{\max} &= 2 \text{ mm} \end{aligned}$$





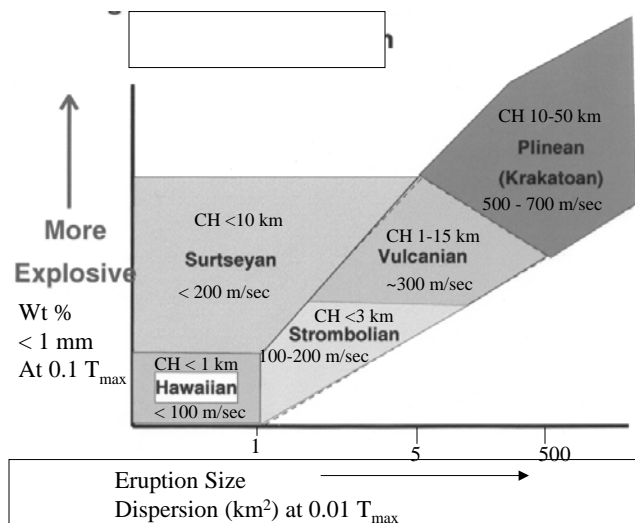


$$\text{Column Height (meters)} = \frac{(\text{Eruption Velocity})^2}{2 \times g} \quad g = 9.8 \text{ m/sec}^2$$

$$\text{Eruption Velocity (m/sec)} = \sqrt{\text{Column Height} \times 2g}$$

$$\text{Eruption Velocity (m/sec)} \approx \sqrt{(\text{Range} \times g) / \sin 2\theta}$$

There are rough relationships between column height, eruption velocity and the dispersion of the ash, that, together with fragmentation of the ash can be used to categorize the various eruption styles



## Examples of Hawaiian eruptions



Fire-fountaining (or  
curtains of fire),  
Kilauea, 1971

Molten magma is ejected  
from cracks to produce  
fire fountains that jet the  
lava 30 -50 feet into the air.



Molten magma hitting the  
ground flows away as lava  
flows, whereas cooled  
magma produces cinders  
(spatter) near the vents.



Kilauea Iki, 1959  
1500 ft high

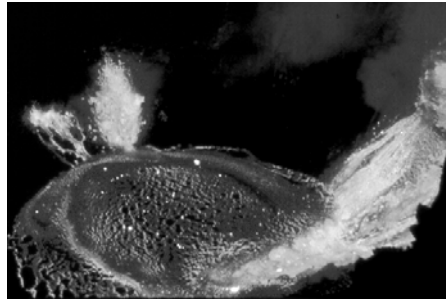


Puu Oo, 1984  
1300 ft high

Magma also jets from single vents, sometimes producing  
fire-fountains over 300 meters high. Again, it may flow away  
as lava or build cinder (spatter) cones.



On Kilauea volcano are many pits or craters. Frequently, lava cascades into these pits to produce molten lava lakes.



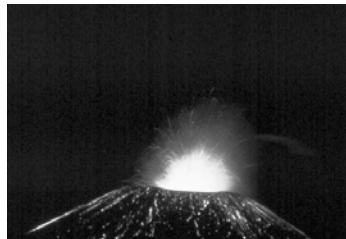
### Examples of Strombolian eruptions



The island of Stromboli



Stromboli erupting at night (note trajectory of volcanic bombs).



A strombolian eruption on Mount Etna, Sicily.

Strombolian eruptions are usually basaltic or andesitic

## Examples of Surtseyan eruptions



Basaltic magma reacts violently with sea water to produce steam. This in turn fragments the magma to produce fine ash which is building a cone. Eventually this cone will grow into an island.



Once the island is formed, and the volcanic conduit is isolated from the sea water, then the eruption becomes much less explosive, resembling Hawaiian style of eruptions.

## Examples of Vulcanian eruptions

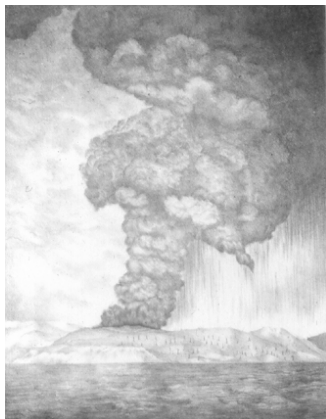


Vulcanian eruptions during the early days of volcanic activity at Mount St. Helens, 1980.

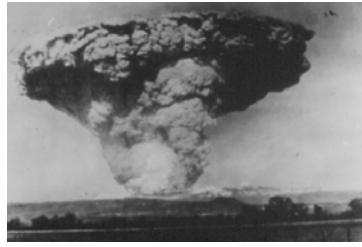
Vulcanian eruptions do not include juvenile material. They are steam-blasts, in which pre-existing rock is fragmented by steam explosions. The steam results from magma heating up ground water.

## Examples of Plinian eruptions

Plinian eruptions are the largest, most violent, and most destructive of all eruptions. They are named after Pliny the Younger, who provided a remarkably accurate description of the 79 A.D. eruption of Vesuvius, Italy.



A painting of the famous Krakatau (Indonesia) eruption of 1883. One of the largest eruptions in history. In some classifications, the term Krakatoan is used instead of Plinian for the sake of consistency.



Lassen Volcano, California,  
1915



Mount Redoubt, Alaska, 1990



Pinatubo Volcano  
Philippines, 1991

Typically silicic, gas-rich  
(rhyolite, dacite or trachyte and  
phonolite) magmas



Hekla Volcano, Iceland, 1980



The eruption  
starts - it is a  
small Plinian  
eruption.



Close-up of the  
eruption column  
(hours later).



After the Plinian stage, Hekla changes to  
a Hawaiian style eruption.