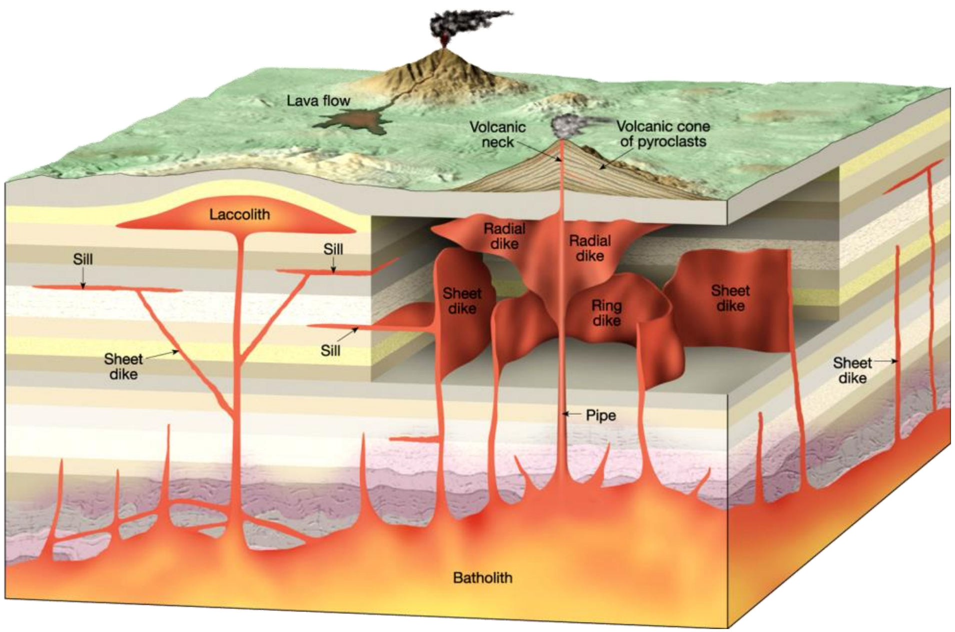
Lava and volcanoes

Lava is magma that made it to the surface through a volcanic eruption

- ✓ How lava makes it to the surface
- ✓ What determines the styles of eruption
- ✓ What material is produced by eruptions
- ✓ Types of volcanoes



How the lava makes it to the surface:

Fissure/rift eruptions

- The rising magma follows the easiest path to the surface, most often <u>along fractures that can extend to the surface</u> generating a fissure eruption
- On Earth, the largest volume of lava is erupted from fissure eruption.


Most fissure eruptions are on the seafloor at Oceanic ridges

How the lava makes it to the surface:

Vent eruptions

- A vent is pipe-like fracture forms and lava issues from it

The lava in Kilauea's crater formed what looks like a smiley face. (Image credit: Mick Kalber/Paradise Helicopters via YouTube) – note embedded video is from a vent in Iceland

- A vent can form anywhere on the volcano, on the flanks and even at the base of it.
- A volcano can have more than one vent

Crater

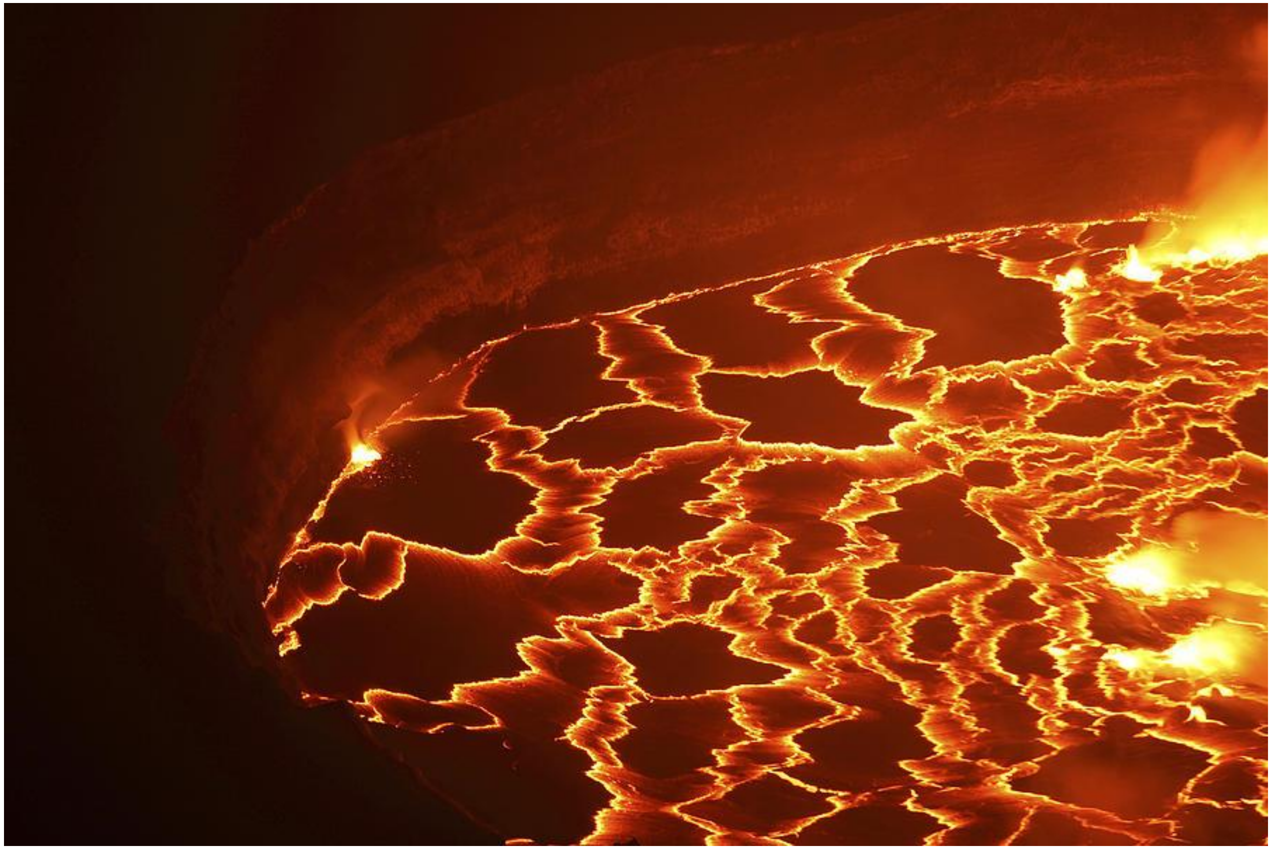
A Crater is a vent with a typical funnel-shaped depression located at the top of a volcano

crater Volcan Villarrica – Central Chile

A near-vertical aerial view into the ~ 250-m-wide summit crater of Villarrica volcano from GVP- Smithsonian Institution

Calderas and lava lakes

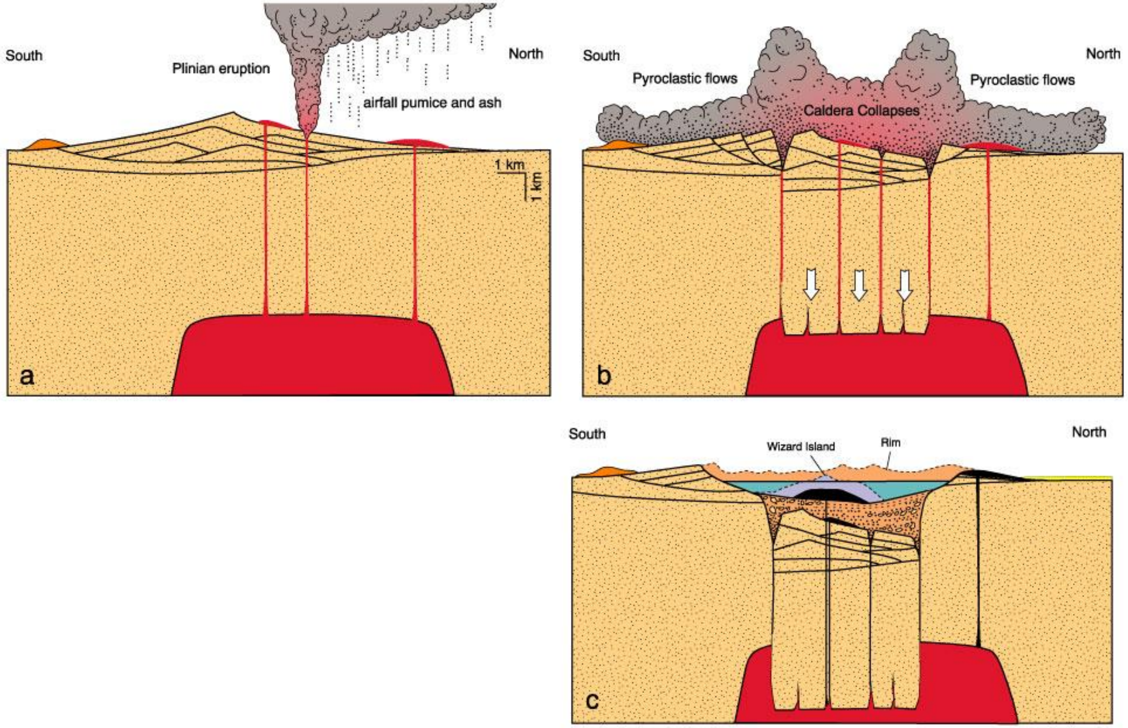
- When the crater is >1 km in diameter it is called a Caldera, a depression that can fill with lava forming a lava lake
- Calderas form when the magma is only a few km from the surface (shallow) so it easily reaches the surface



Lava Lake In Summit
Caldera, Nyiragongo
Photo by John Seach

Caldera formation

- A caldera forms when the magma pools close to the surface (3-5 km).
- This way, magma can more easily break through the crust and erupt through many fractures reaching the surface
- As the magma escapes, the roof of the caldera collapses forming a depression that can fill up with water (e.g. Crater Lake caldera of Crater Lake National Park, Oregon)



A Caldera can contain several craters.

Kilauea
Hawaii

Style of Volcanic eruption

- **Composition of magma**

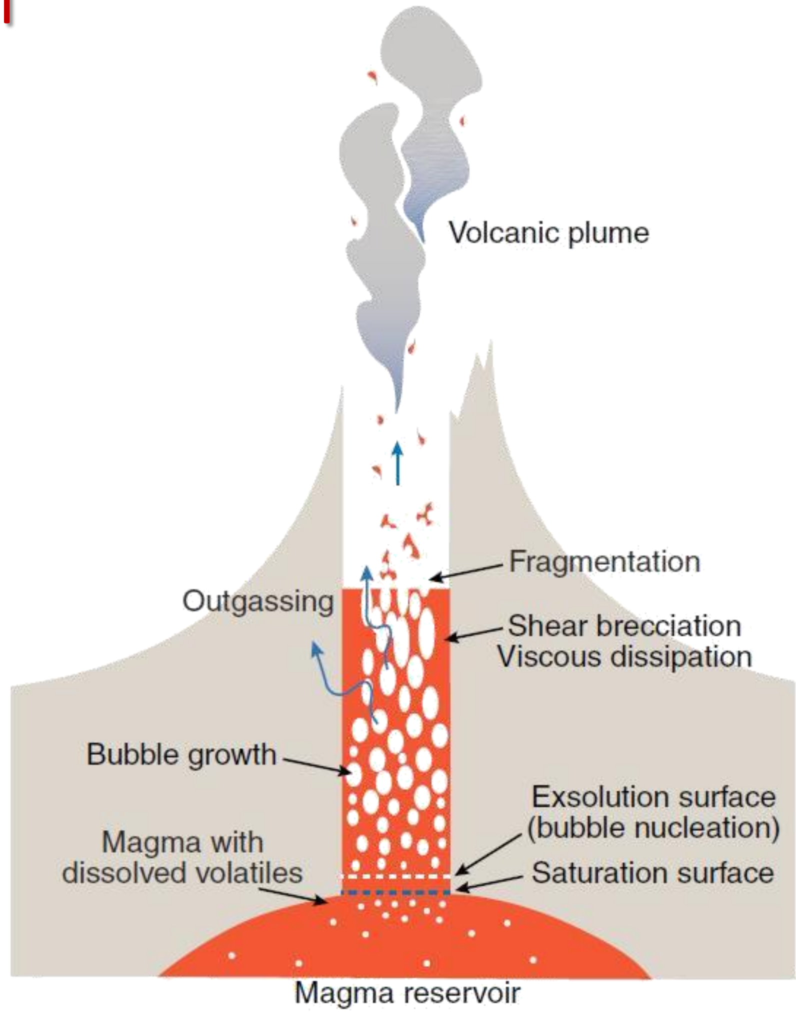
More silica → higher viscosity*
Less silica→ higher fluidity

- **Temperature of magma**

Lower temperature → higher viscosity*
Higher temperature→ lower viscosity*

- **Role of the volatiles**

Pressure keeps the volatiles dissolved in the magma. When the magma reaches the surface, the volatiles (H_2O, CO_2, SO_2) expand, move upwards to escape



Viscosity* →resistance to flow; it depends on both temperature and composition

Effusive Eruptions

basaltic lava rich in Fe, Mg
high Temperature, low viscosity → degasses quickly and may form lava fountains

Explosive Eruptions

Felsic lava rich in silica and feldspars
low T and high viscosity → holds onto the volatiles, until they expand to generate an explosion

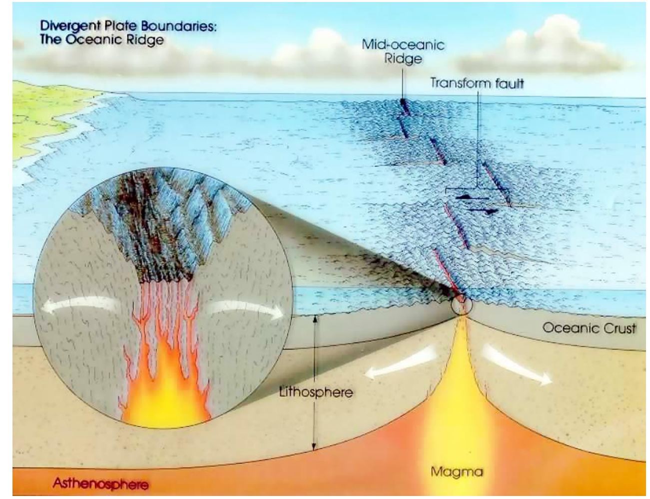
Pu'u O'o eruption Hawaii

Shiveluck volcano, Russia

Effusive eruption: Lava

- Erupted as a flow during an effusive eruption
- Lava fountains are effusive eruptions of high temperature lava with relatively high volatile content

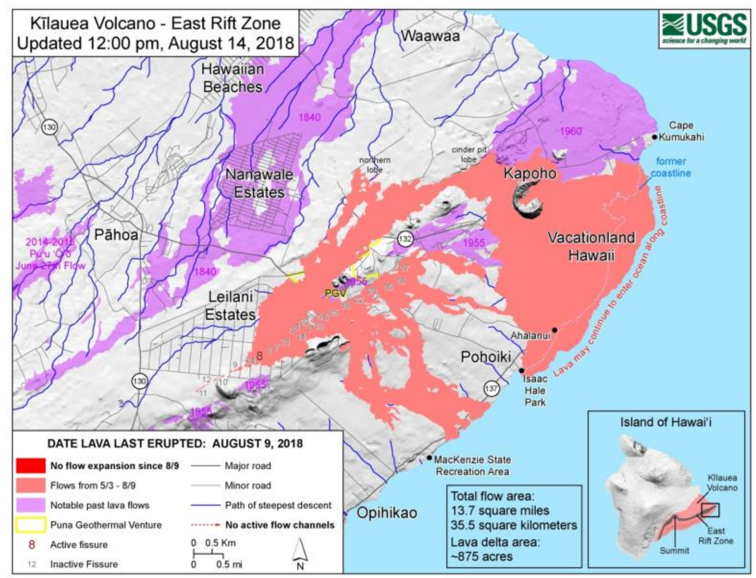
Largest effusive lava eruptions



Rift eruptions of basalt (mafic) lava are most common at divergent plate boundaries where it forms oceanic lithosphere

and

at Hot Spots like Hawaii

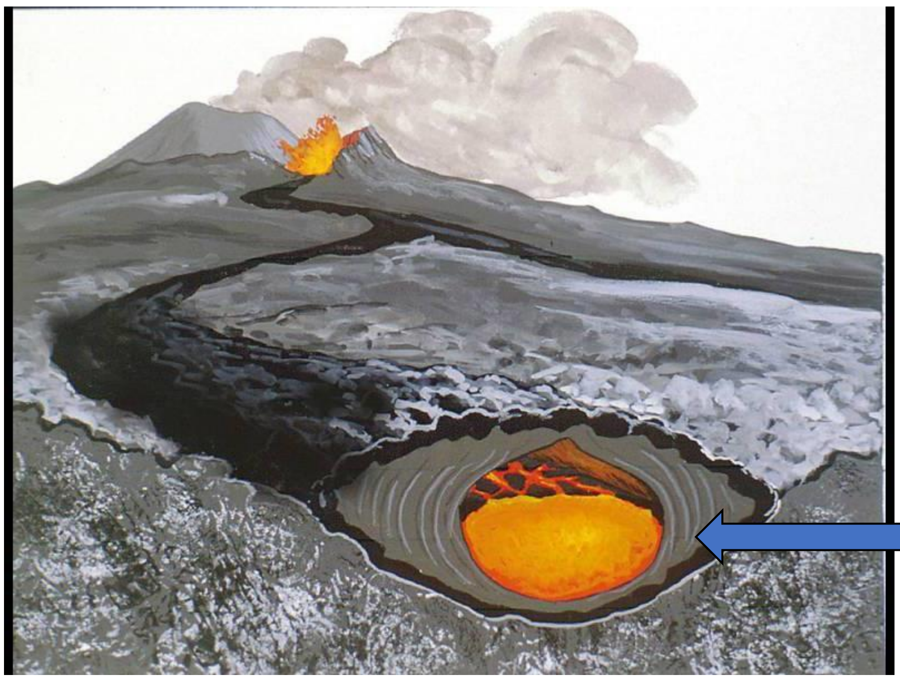


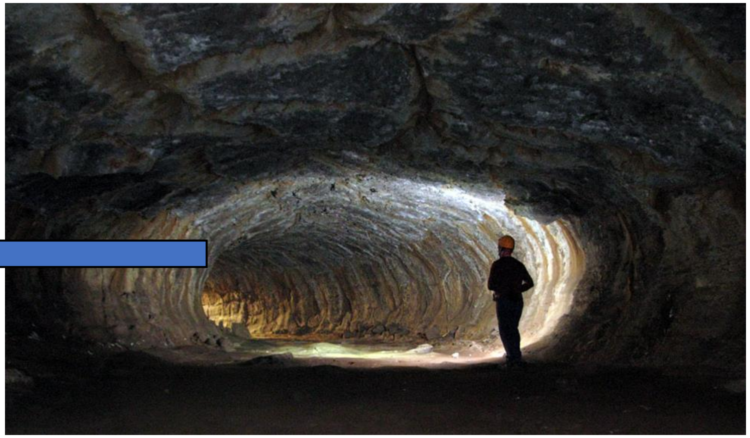
Lava flow texture

- Pahoehoe (rope-like) – slow rate of heat loss
- Aa (crumbly) – fast rate of heat loss

Lava tube

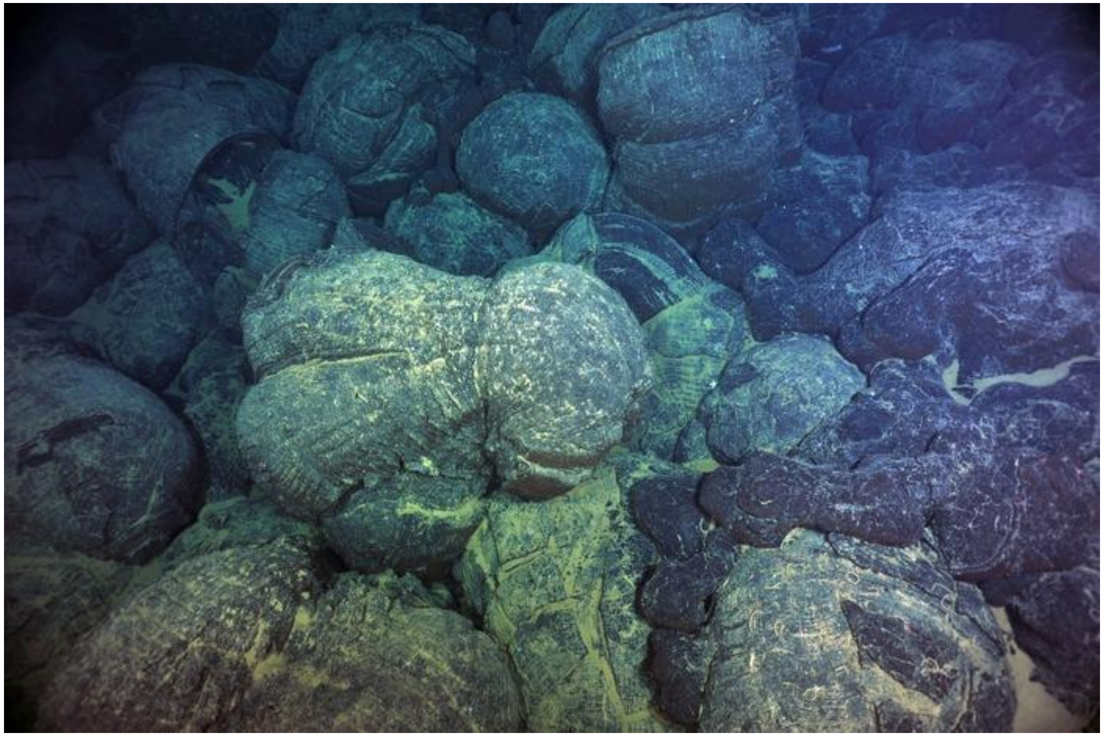
- The outer portion of a lava flow, in contact with cool air (25C) tends to cool and crystallize faster than the inner portion of the flow, while the hot inner flow keeps flowing, leaving behind a tunnel-like structure, the lava tube.
- The highly fracture roof of the lava tube often collapses providing a skylight





Pillow Lava

- When lava erupts underwater, the great pressure of the water forces the lava to cool fast, taking a mound- shape called pillow lava
- Lava erupted at divergent plate boundaries on the seafloor has this structure



Intermediate and felsic lava flows

- Less common than the mafic lava
- Lower temperature is more viscous.
- Erupt mostly from vents and accumulates on/near craters forming a volcanic Dome

Mt. St. Helens Dome

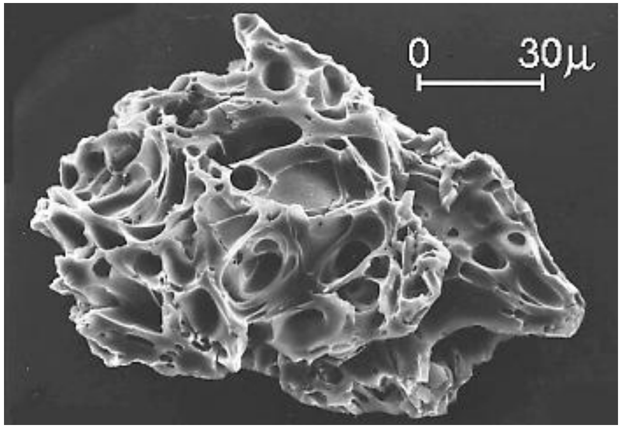
Explosive eruption: tephra

- Tephra - or pyroclastic material - is the product of lower temperature, higher viscosity eruptions of magma with <u>high volatile content</u>

Classification of Tephra

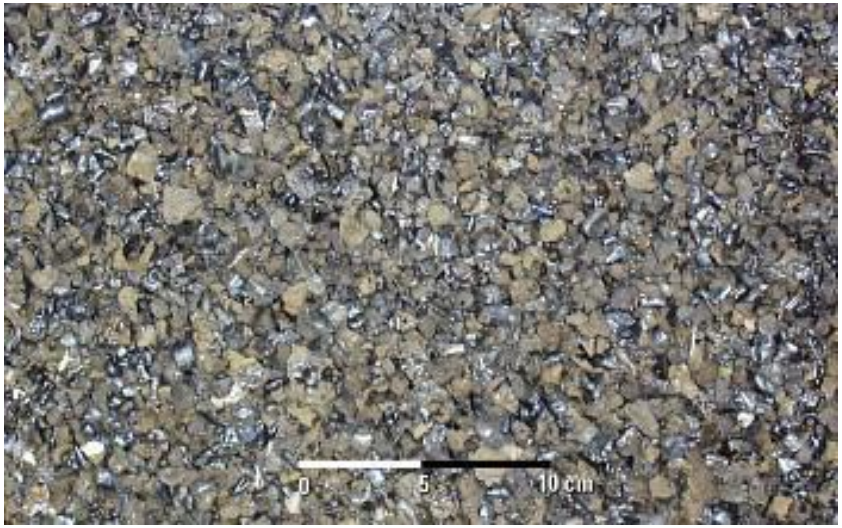
- Tephra is classified by size. The finer size is called ash

- Ash is mostly made of fine, glassy fragments with vesicular texture



- Ash is the main solid component of the eruption column/cloud

Lapilli pebble-sized material



(Pasquale Sorrentino)

Volcanic debris including lapilli, or solidified lava, and thick layers of compressed ash from the A.D. 79 eruption of Mount Vesuvius surrounds the doorway to a partially uncovered entranceway in Regio V.

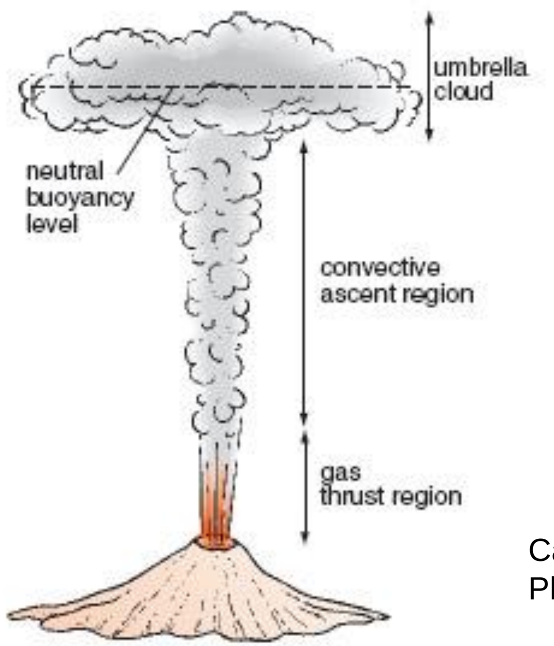
Blocks are hardened or cooled lava. They might be part of the volcanic neck or dome shattered by the explosive eruption.

Blocks can range in size to be as big as small buildings

Lava Bombs - ejected as hot lava, they acquire their shape as the material cools

Tephra Column/Plume

- The explosion forms a column of volatiles and finer tephra that rises until it reaches the neutral buoyancy level where it spreads out
- The height of the column depends on the strength and size of the eruption.



Calbuco, Chile, explosion on 22 April 2015, taken about 30 km SW of the volcano. Photo by Keraunos

Eruption of Mt. Pinatubo, Philippines, 1991

Pyroclastic flows

- Pyroclastic flows are mixtures of tephra and volatiles at <u>supercritical condition</u> so the mixture behaves like a fluid and flows down the side of the volcano.
- The proportion volatiles-to-tephra can vary, there are pyroclastic flows of various density and speed.
- Pyroclastic flows can travel at velocity of 100kms/h and even move uphill.
- <u>Example Merapi Indonesia footage 2019</u>
- <u>Second example: Sinabung</u>

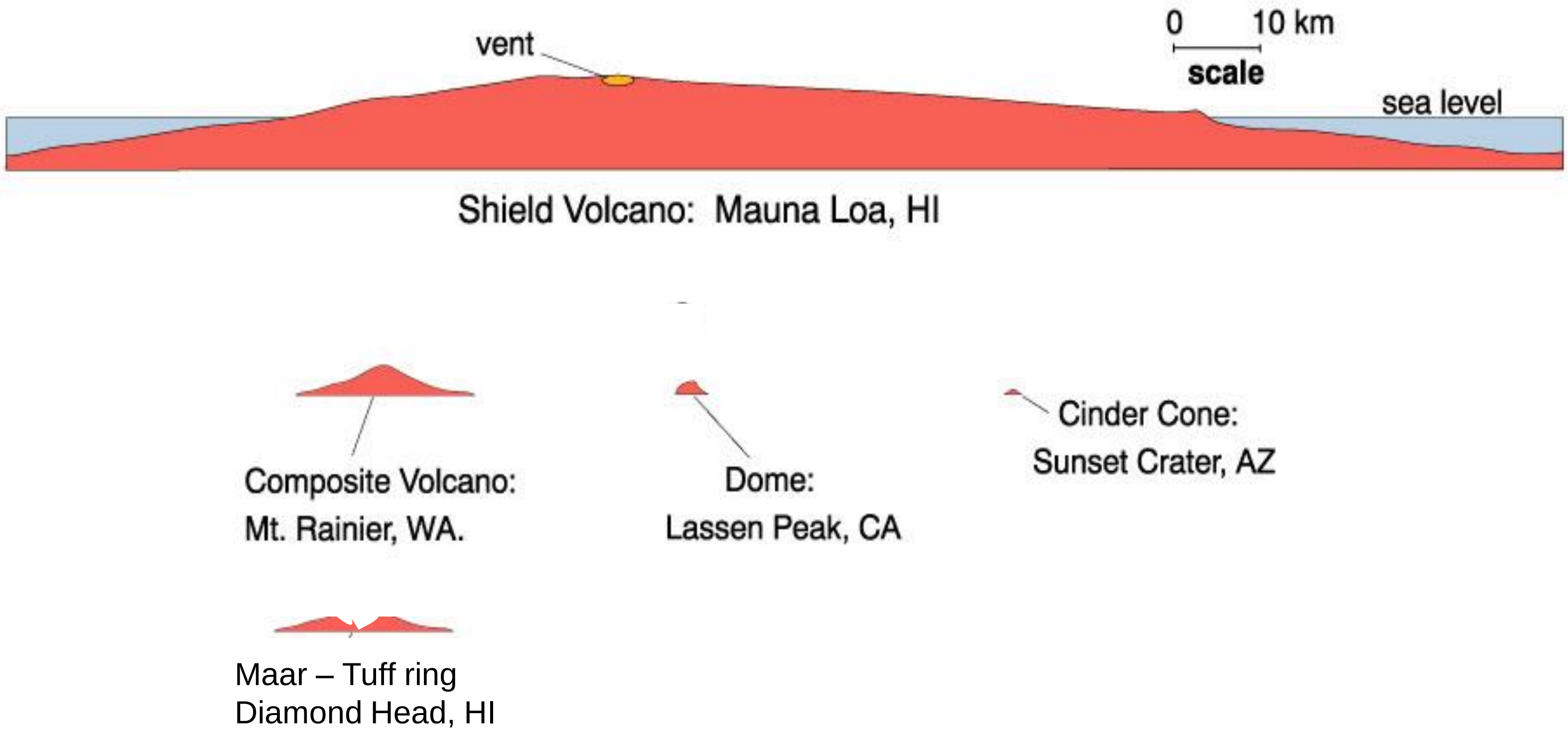
Volatiles only eruption: Fumaroles

- Vents/fractures from which volatile eruptions occur, often accompanied by deposits of sulfur and other minerals

Fumaroles @ Yellowstone NP

Types of volcanic structures

Volcanic landforms associated with a central vent (all at same scale).

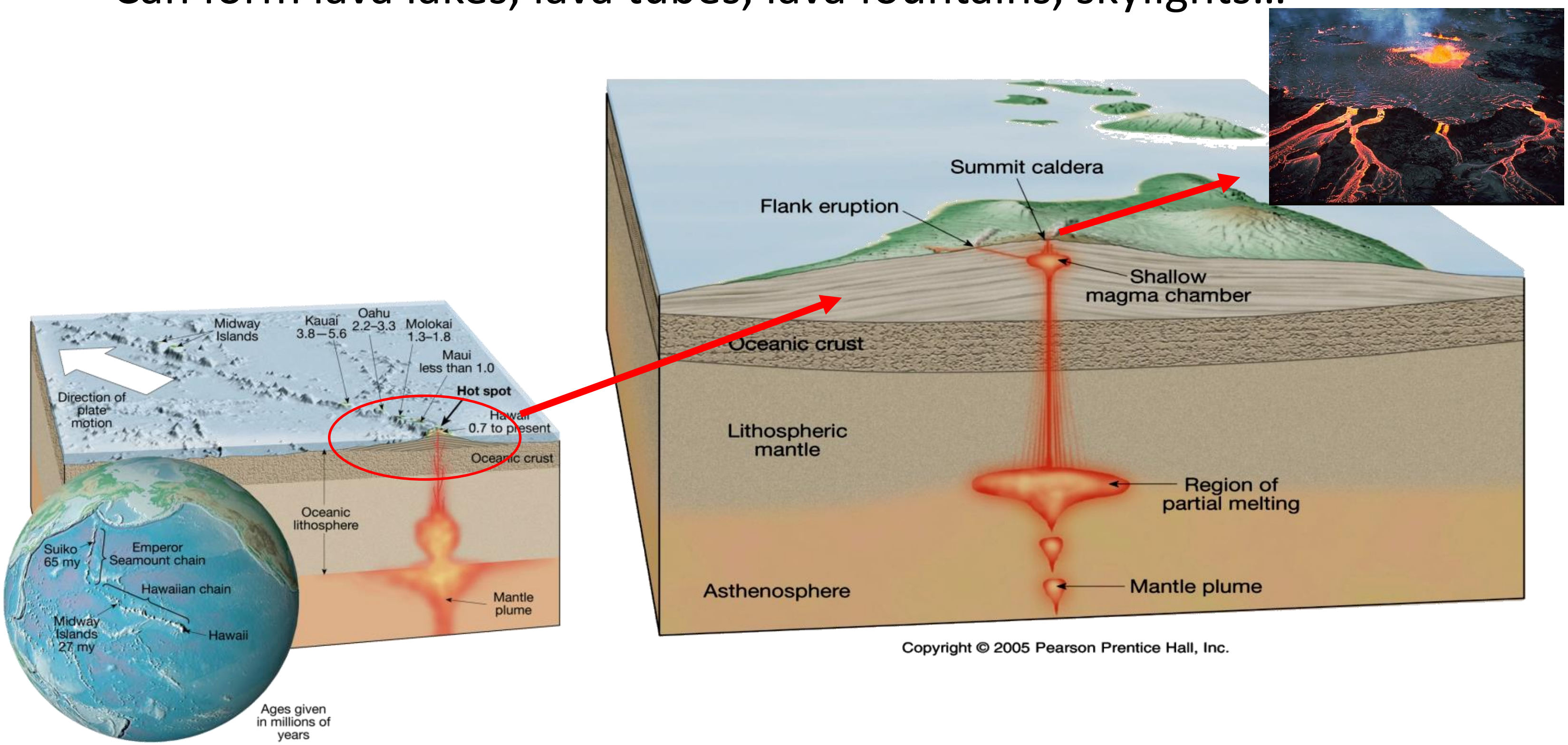


Volcanic landforms associated with fissure eruptions.

Volcanic Plateau: Columbia River Basalt, OR

Shield volcano

- Form @ hot spots because of mantle plumes
- Broad, slightly dome-shaped, there area can cover hundreds of square km
- Produce large volumes of basaltic lava
  - Example = Mauna Loa on Hawaii
  - This volcanoes have calderas, rifts fissure eruptions
  - Can form lava lakes, lava tubes, lava fountains, skylights…

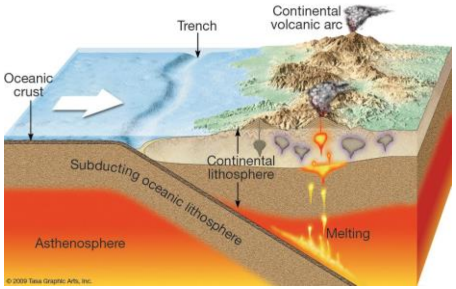


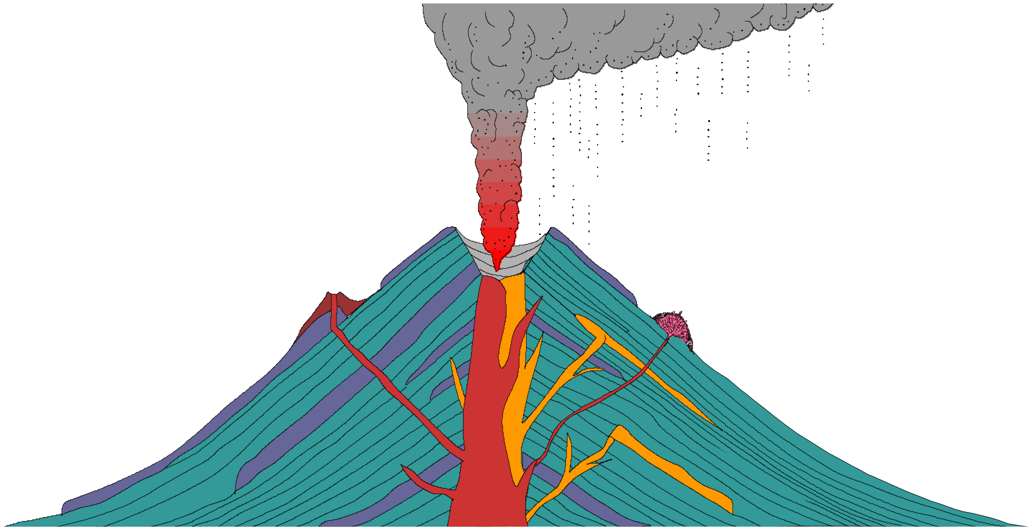
Eruptions on shield volcanoes can occur from calderas (l) and rifts (r)

Kilauea, Hawaii

Stratovolcano/composite

- Form @ convergent plate boundaries where there is subduction





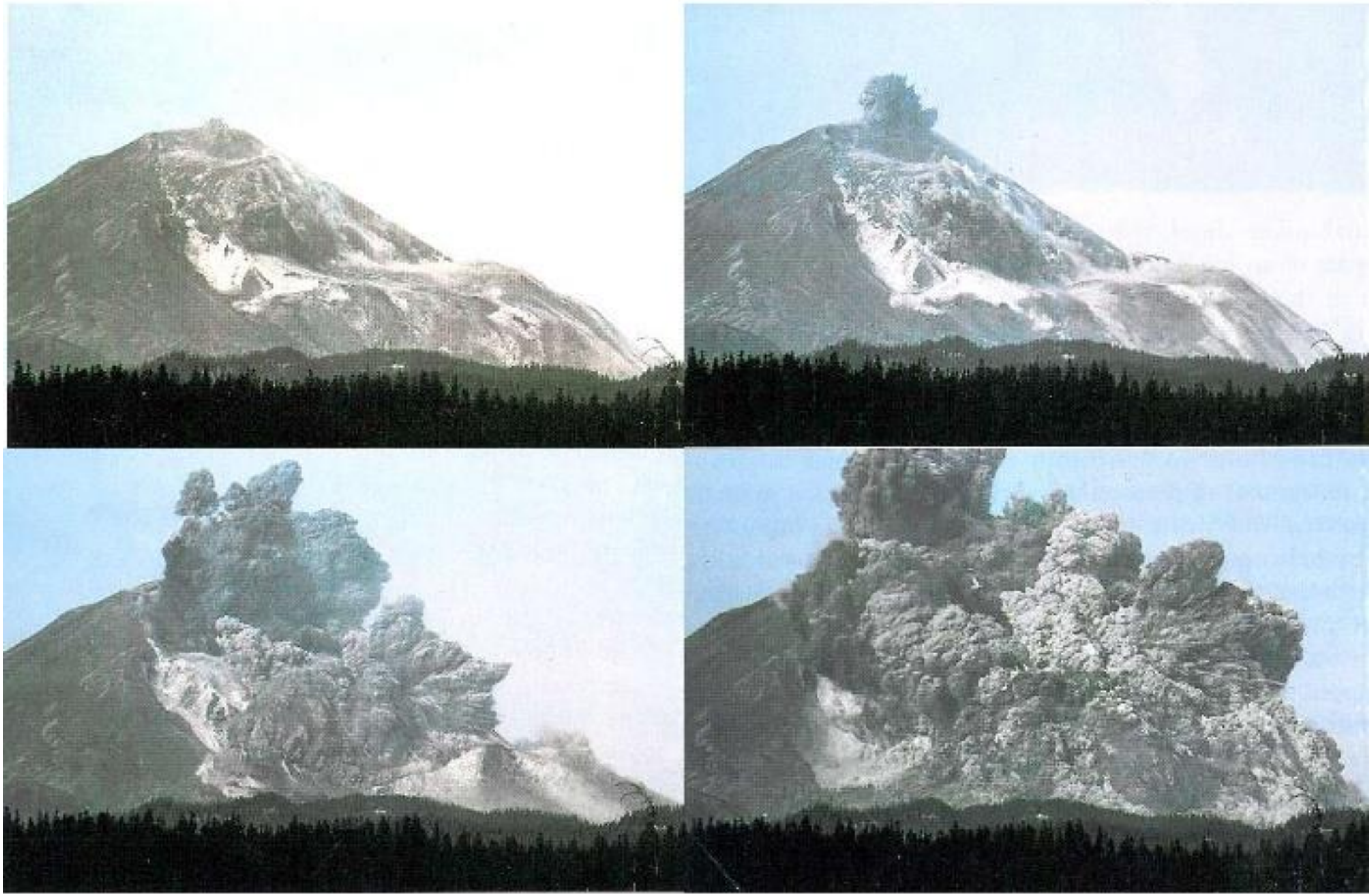
- It has a typical cone shape, formed by sequences eruptions explosive and effusive, forming layers of lava and tephra

- The Cascades of the western side of north America are stratovolcanoes

The explosive stratovolcano case study Mt. St. Helens

Mt. St. Helens weeks before the eruption

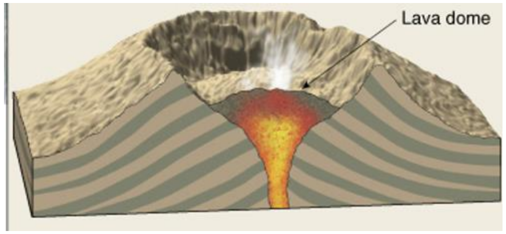
Photo showing that the eruption started with the collapse of the flank

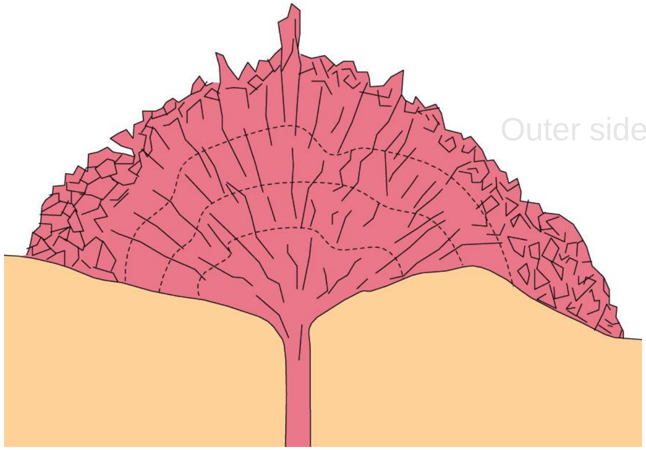


Just after the 1980 eruption

Lava Dome

- Form from effusive eruption of viscous, degassed, low temperature lava, intermediate to felsic in composition
- Associated with stratovolcanoes





Outer side fractures

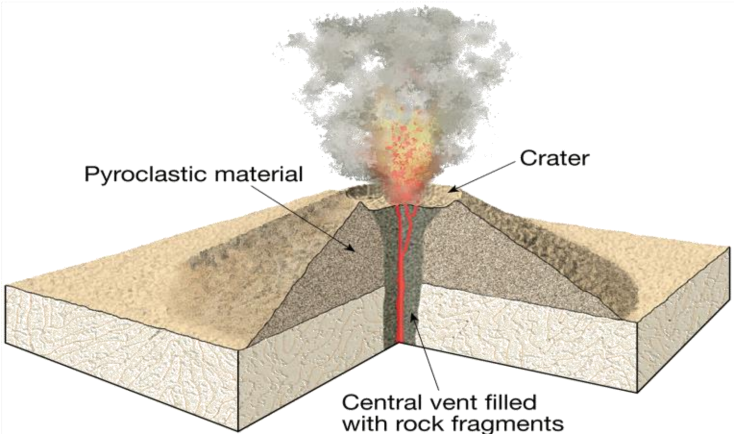
Dome, Volcan de Colima

Paluweh, Indonesia

Mt. St. Helens dome

Scoria/Cinder Cone

- Small volcanoes that form over vents erupting high temperature mafic lava, commonly with lava fountains
- Built from lapilli to block-sized fragments of scoria
- Shape: Cone-section with gentler slope than stratovolcanoes
- Occur in groups

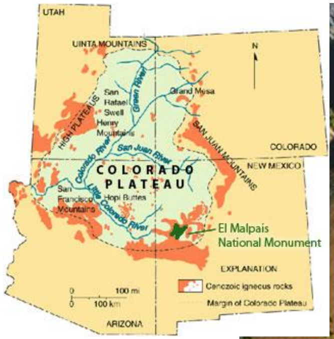


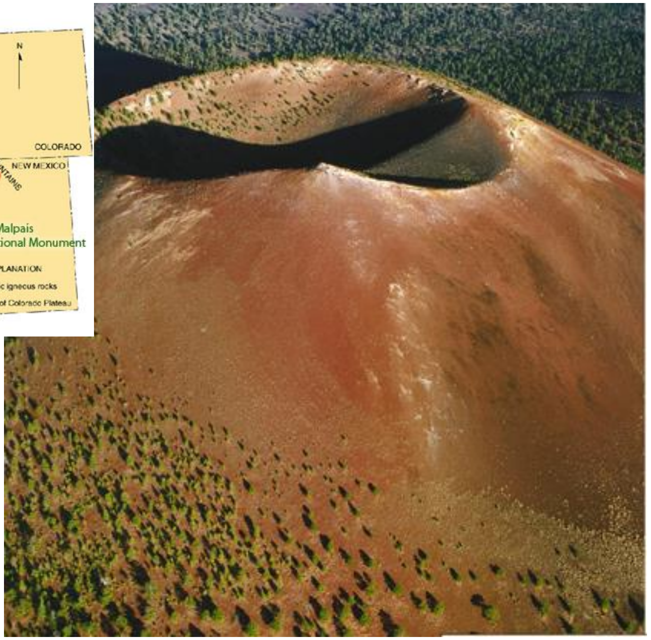
Cinder cone on Etna, Italy 2020 eruption

Cinder cones

The volcano began as a fissure in a cornfield owned by a P'urhépecha farmer, Dionisio Pulido, on February 20, 1943

[Paricutin, Mexico]





Sunset crater, USA

Cinder cones in the Haleakala crater, Hawaii

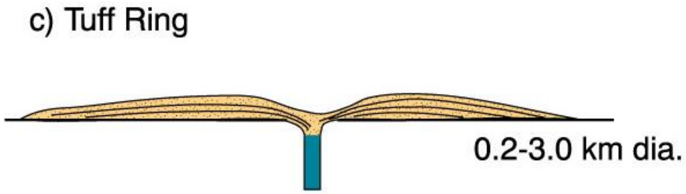
Hydromagmatic eruptions: Tuff rings

• if rising magma encounters water stored in the ground, the heat turns the water into vapor generating a hydro-magmatic explosion

- These eruptions can happen on dry land but also in submarine environments: the January 2022 eruption in the Tonga area was one of these eruptions

The explosion forms a funnel-shaped depression mostly filled with the eruption debris.

• If the crater is at higher elevation than the surrounding ground, the structure is called a Tuff Ring



Hydromagmatic eruptions: Maar

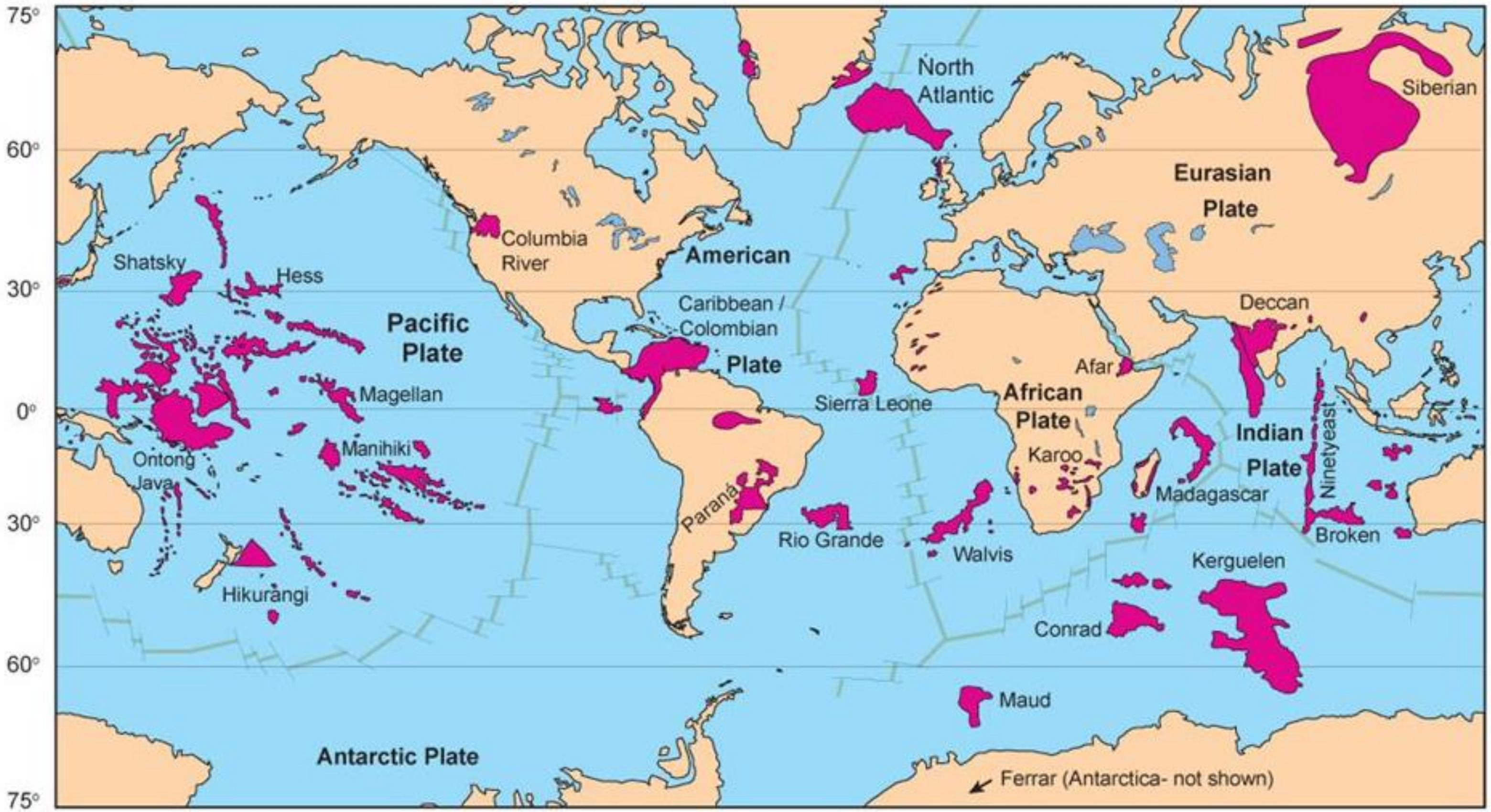
Zuni Salt Lake – NM maar, with cinder cones

- Maars are produced when the explosion leaves a crater in the ground that is below the level of the surrounding landscape
- A maar can host lakes if in temperate/humid climates

“hole-in-the-ground”, OR

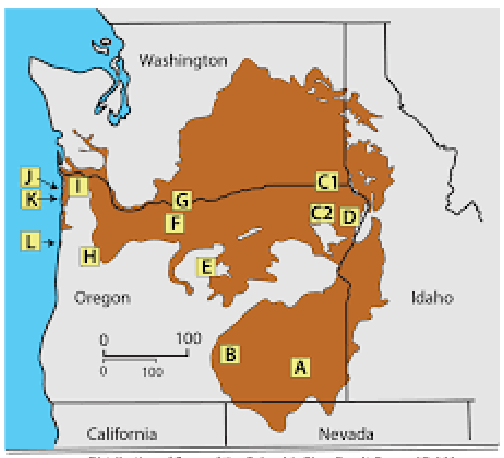
Volcanic plateaus

Rift-fracture eruptions at hot spots can cause massive eruptions of mafic lava called Volcanic Plateaus
Their formation was caused by series of basalt “floods”



Columbia River Basalt Flood

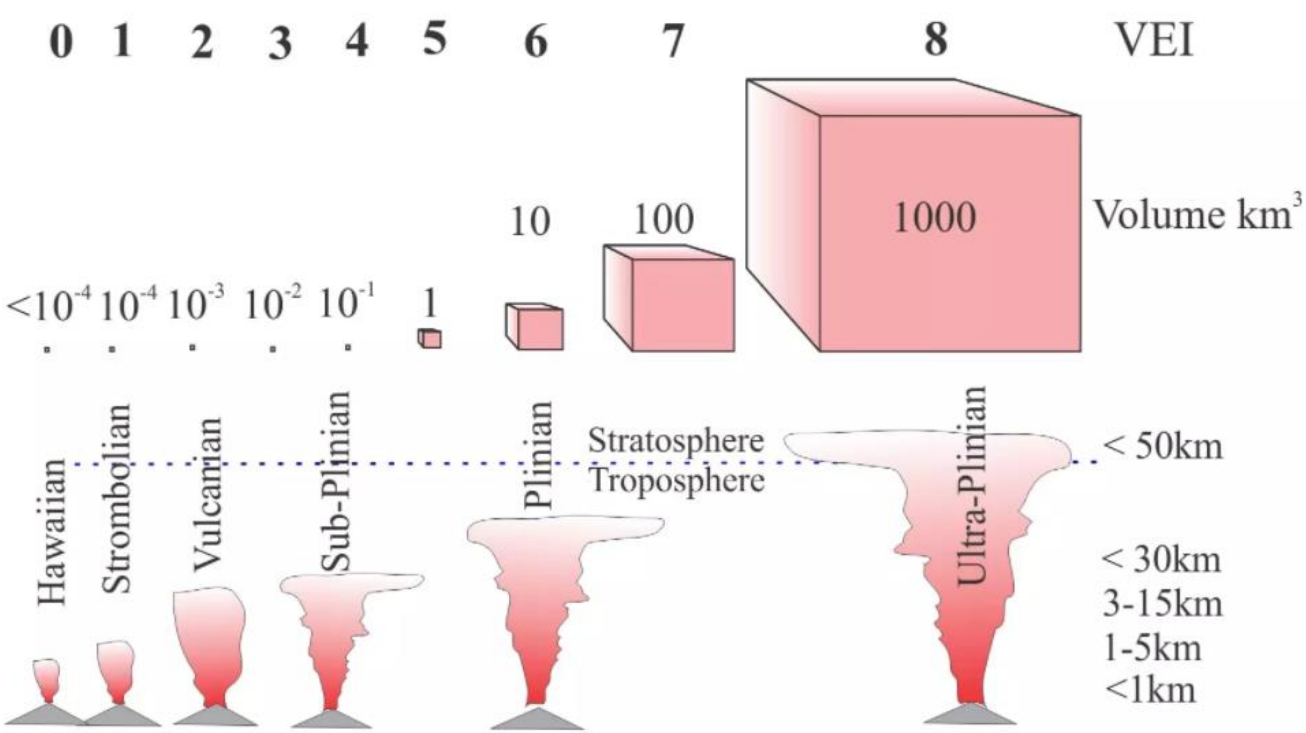
- Massive eruption after eruption from rift/fracture, build up layers of lava, highlands of thick layers of volcanic rocks
- The Columbia River Basalt flood formed between 17 and 15 million years ago



Distribution of flows of the Columbia River Basalt Group, 17-6 Ma
(Modified from Reidel and others, 2013)

Classification of eruptions

- The magnitude of a volcanic eruption is measured as VEI, volcano explosivity index, based on the volume of erupted tephra
  - The VEI has 8 degrees, Mt. St. Helens 1980 eruption had a VEI=4, Mt. Vesuvius 79 AD VEI=5, Yellowstone caldera 600ky VEI=8
  - In the past, the eruption magnitude was estimated based on the height of the eruption column, named after major historical eruptions



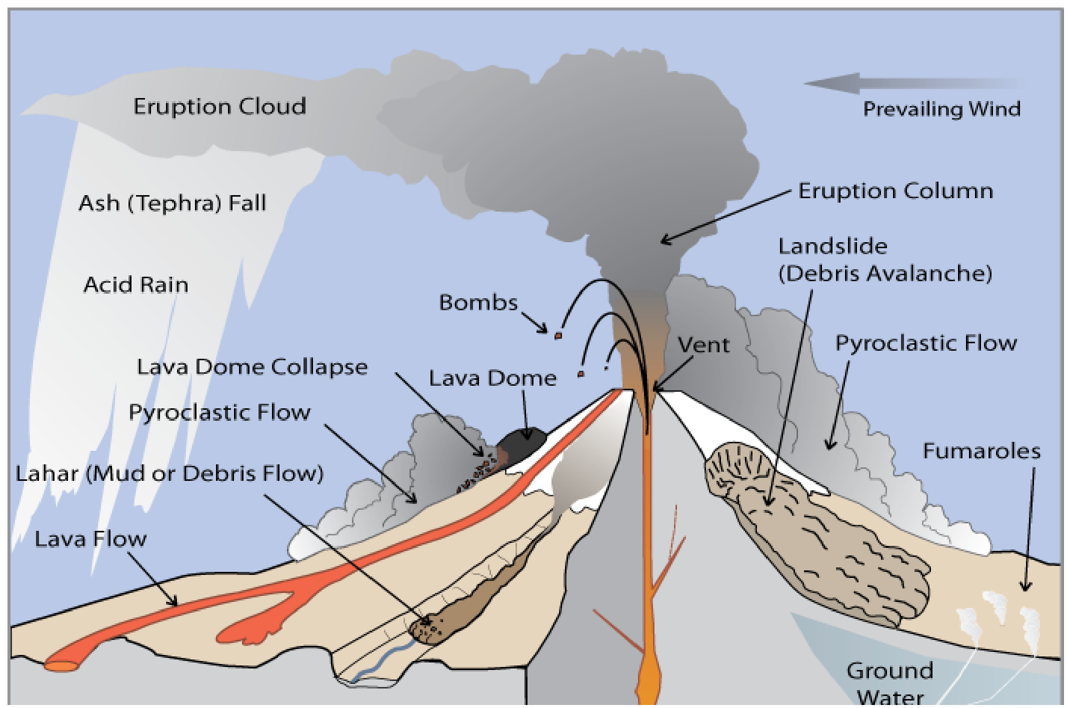
Extinct volcanoes?

- Volcanoes are built by many eruptions over long time, often millions of years.
- A volcano may erupt for days to years and then take long periods of quiescence → dormant volcano.
  - A non erupting volcano can be covered with vegetation, have a glacier on top, but it is still an active volcano!
- <u>A volcano is active as long as the conditions for magma generation occur.</u>

Volcanic Hazards

Volcanic hazards are processes and products of volcanic activity that jeopardize human lives and interests. The most common volcanic hazards are:

- Lava
- Tephra fall
- Pyroclastic flows
- Lahars (mudflow)
- Volcanic gases

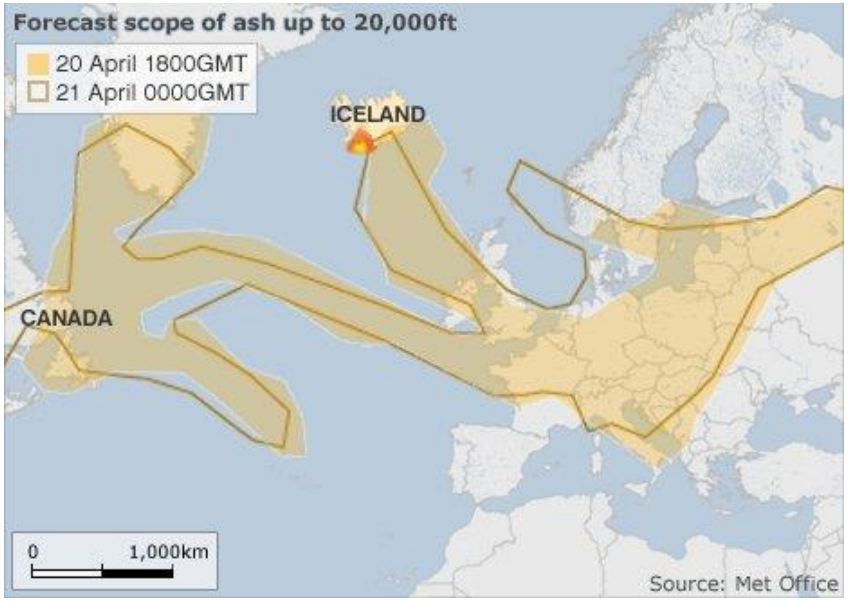


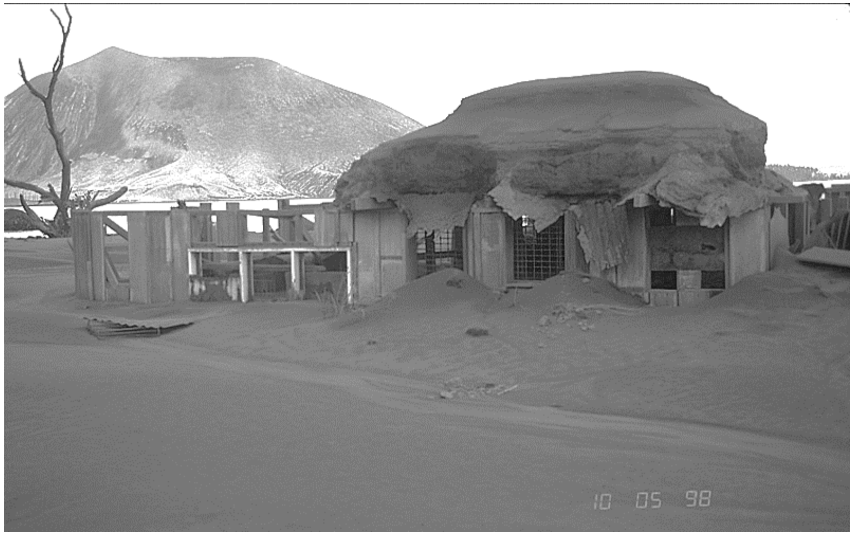
Lava Hazard

Lava burns/buries anything on its path

Tephra Fall hazard

- While at high altitude it is a hazard for airplanes to fly into
- When it falls on the ground, it generates significant damage to buildings, infrastructures, farmland etc.





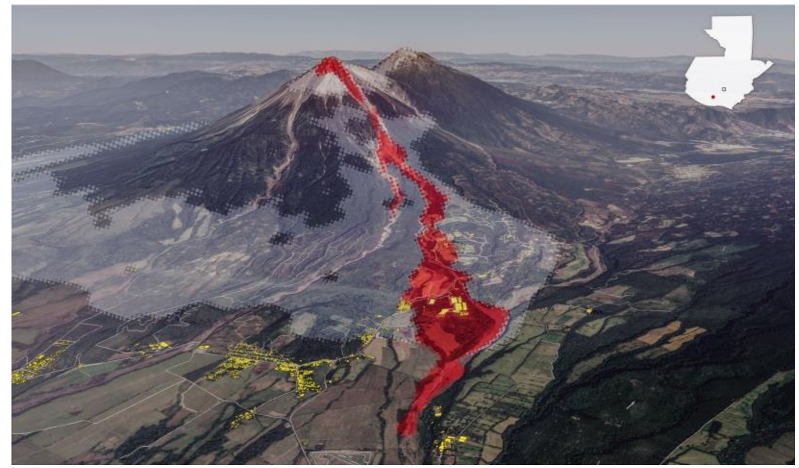
Case study of tephra fall and pyroclastic flows:
Vesuvius eruption 79 AD - Pompeii and Herculaneum
[footage Mt. Vesuvius]

Pompeii: Victims of the tephra tried to hide their face and/or crawl on the ground to escape the intense fall of lapilli and the gases

Herculaneum: victims died suddenly by the intense heat

Pyroclastic flow Hazard

- Travels fast, it can cover long stretches of ground
- It burns and destroys everything on its path
- Example: eruption of Volcan Fuego, Guatemala 2018



San Miguel Los Lotes

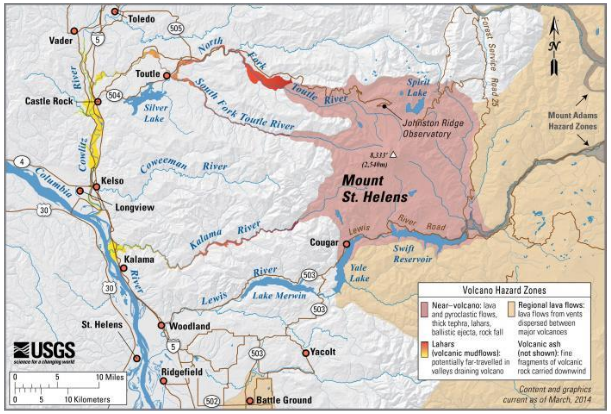
Feb 5, 2018   June 6, 2018

Lahar or Mudflow

- A mixture of water (from heavy rain or melting snow) and volcanic material (ash to large boulders)
- The mixture flows down the slope of a volcano following the valleys

Lahar on Mt. Ruhapehu Volcano, New Zealand

Case study: the Mount st. Helens Lahar



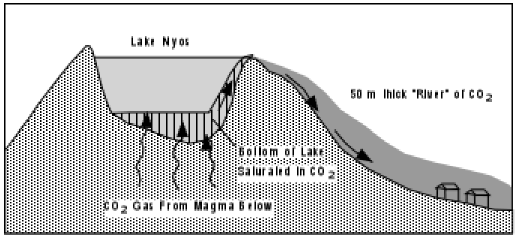
Volcanic Gas hazards

- Volcanic gases are poisonous, two most common are

  Sulfur dioxide → acid rain and air pollution

- Carbon dioxide → heavier than air → may flow into in low-lying areas, collect in the soil and be lethal to people, animals, and vegetation.

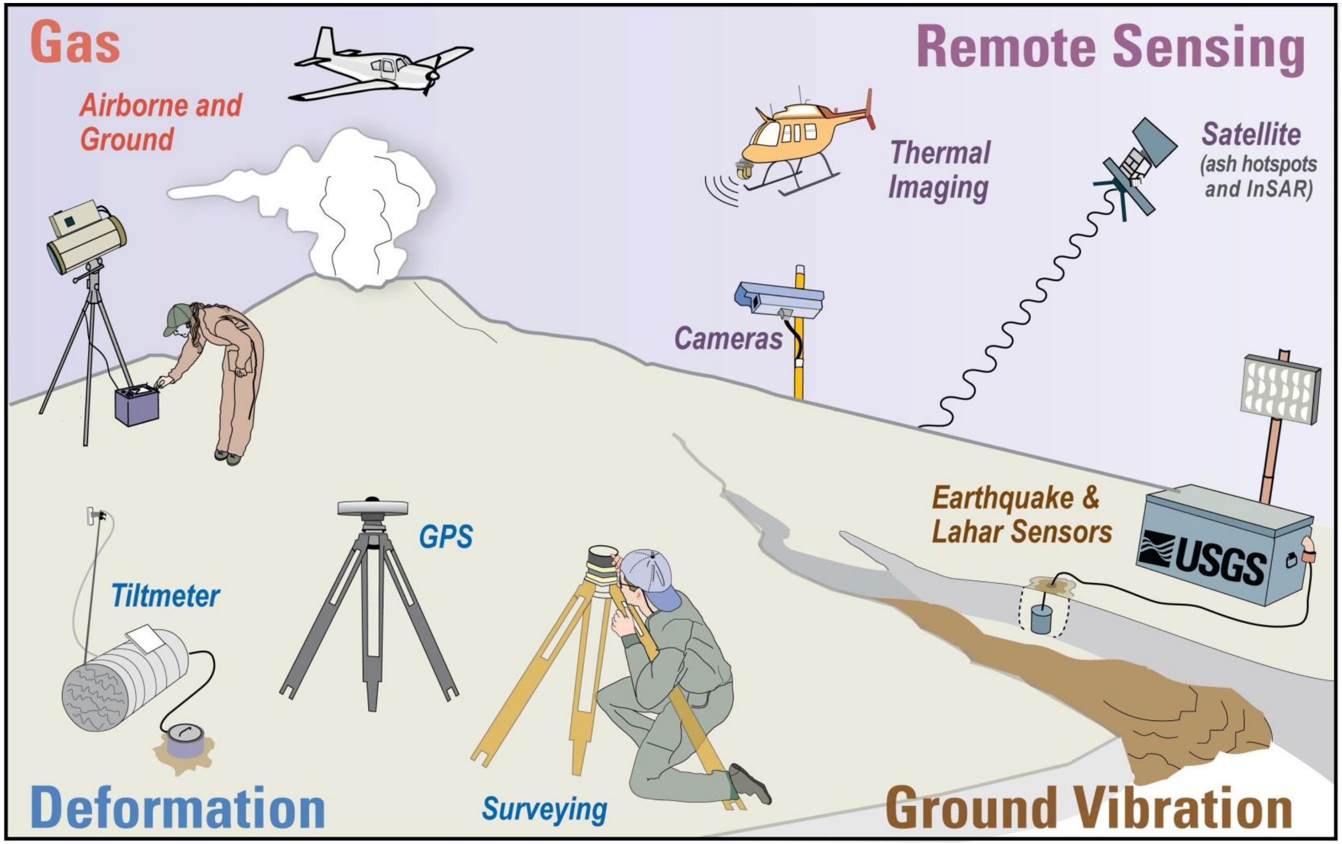
Lake Nyos Cameroon
1986



After Abbott, 1996

Assessing volcanic hazard

- We cannot prevent a volcano from erupting
- We cannot predict volcanic eruptions, but we can monitor the physical processes that indicate lava movements within the volcano edifice that might lead to an eruption.



Monitoring volcanoes

- Monitoring is dome by using a variety of techniques that can detect activity inside a volcano
- Assessing seismicity
- Measuring deformation of the ground
- Measuring volatile emissions from the ground