### LECTURE #10 : Volcanic Disasters: Lava Properties & Eruption Types

#### Date: 17 February 2025

#### I. Volcano Introduction

- why study volcanoes?
  - o two main reasons:
    - hazard mitigation
      - ~ 700 million people (~ 9% of the global population) are living in harm's way of volcanic activity
      - $\succ$  ~ 270,000 deaths in last 500 years
        - average of ~ 500 deaths/year
      - ➤ ~ 70,000 deaths since 1900
        - largest: 92,000 (Tambora, Indonesia –1815)
        - next: 36,417 (Krakatau, Indonesia 1883)
    - primary geologic process that has operated throughout Earth's history along with impact cratering
- what is a volcano?
  - manifestation at the surface by the release of a solid/liquid/gas due to internal heat processes of a planet
- two prerequisites needed for volcanic activity:
  - something to melt
  - o and a source of heat
  - o important to realize that not all volcanoes are like Hawaii (or Mt. Etna)!
- average global production of lava:
  - $\circ$  2 km<sup>3</sup> per year (land)
    - equivalent to a 4,120 foot cube
  - 20 km<sup>3</sup> per year (ocean floor)
    - divergent plate boundaries
  - o many types and styles other than Hawaii
    - water/steam eruptions (Yellowstone Nat'l Park, USA)
    - carbonate magmas (Ol Doinyo Lengai volcano, Africa)
    - very explosive volcanoes (Pinatubo volcano, Philippines)
- heat
  - $\circ$  the heat loss by lava comes from convection, conduction, radiation
  - the latent heat of fusion
    - heat required to melt one kg of material to its melting point
      basalt = 1.96 x10<sup>6</sup> (~ 2 million) Joules (J)

- by comparison, the total world energy production in 1998 was 4.0 x 10<sup>20</sup> J
- now it is: 5.7 x 10<sup>20</sup> J
  - > that could only melt about  $2.1 \times 10^{14}$  kg of basalt
  - > what Kilauea Volcano produces on average in just **5 hours!**

#### **II. Physical Properties of Lava**

<u>دع</u> د	<u>c<b>trusive</b></u> Basalt	<u>Intrusive</u> Gabbro	<u>Color</u>	<u><b>SiO2%</b></u> <52	<u>Temp (°C)</u> 1000-1200
0	Andesite	Diorite		52-63	950-1200
0	Dacite	Granodiorite		63-68	800-1100
0	Rhyolite	Granite		>68	700-900

- effects of volatiles
  - o volatiles are any dissolved gas or liquid composition in a magma
    - most common are: H<sub>2</sub>O, CO<sub>2</sub>, SO<sub>2</sub>, CO, H<sub>2</sub>S ...
  - $\circ$  in general, all volatile species are lumped as one value for the melt
    - at high pressure, volatiles are in solution (no bubbles) → lowers the viscosity
      - > just like the gas in an unopened Coke bottle
      - when it is opened, pressure is released and the volatiles come out of solution (form bubbles)
    - volatile can be as high as 20% by <u>mass</u> at high pressures underground
      - however, volatiles have low molecular weights and therefore can be an even larger <u>volume</u> of the melt
      - the more volatiles in a melt, the more potential for an explosive eruption when the magma gets close to the surface!
  - Viscosity (η)
    - internal resistance to flow (strain) by a substance when subjected to shearing (stress)
    - it is the "sluggishness" of a fluid
    - o important higher the viscosity, the higher the explosive potential
    - o depends on other factors of the material, such as:
      - temperature, phenocryst/bubble content, volatile content, SiO<sub>2</sub> content, pressure, etc.
      - factors: silica content (SiO<sub>2</sub>)
        - ➢ increase in SiO₂ → increase in viscosity

Si:O	<u>η (Pa*s)</u>	<u>rock type</u>
1:2	0.02	basalt
1:3	2.8	andesite
1:4	1 x 10 <sup>9</sup> (1 billion)	rhyolite
	. ,	dive ail = 0.00 (water

- <u>factors</u>: Temperature (T)
  - ➢ increase in T
  - > decrease in crystallization, # atomic bonds, hence viscosity



# III. Lava Types/Composition

- basalt composition
  - dark igneous rock characterized by small (<1 mm) grains with equal proportions of plagioclase feldspar and pyroxene
    - SiO<sub>2</sub> from 45 to 55%
  - produced by partial melting of upper mantle material
  - in general, same as the bulk composition of the terrestrial planets (moon, Mars, Venus, etc.)
  - these lavas form *shield-shaped* volcanoes
- andesite composition
  - lava production at subduction zones
  - dominated by fluids from ocean slab driven into the overlying mantle of the continental crust
    - melting occurs when the H<sub>2</sub>O lowers the melting point of these rocks and magma forms
    - these lavas form composite (or cone-shaped) volcanoes





- hydrous (wet) magma
  - at 90 km depth (mantle) 20 wt.% H<sub>2</sub>O is possible in the melt
  - very "wet" andesite lavas at the surface are only ~ 3 wt.% H<sub>2</sub>O
    - average basalts are < 0.1 wt.% H<sub>2</sub>O
    - so, where does all the water go?
- rhyolite composition
  - also produced at subduction zones or other large volcanic centers
  - very high SiO<sub>2</sub> content (>70%)
  - very high H<sub>2</sub>O content (>5%)
    - results in high viscosity ("sticky") wet magma
    - very explosive
      - $\succ$  if the H<sub>2</sub>O forms bubbles
    - or very thick flows
      - if the H<sub>2</sub>O escapes before large bubbles form leading to an eruption



## IV. Eruption Types/Styles

- Hawaiian Style
  - some explosive activity, mostly effusive (flows on the surface)
  - low eruption columns (fire fountains)
  - o forms spatter and cinder cones
  - o typically basalt
    - example: various Hawaiian eruptions



- Strombolian Style
  - o low ash columns, more energetic than Hawaiian
  - $\circ$   $\,$  forms cones and sheets  $\,$
  - o basalt or andesite
    - example: Hekla (Iceland), 1970, Etna (Italy), 2021
- Pelean Style
  - o collapse of a lava dome
  - $\circ$   $\,$  large ash columns are rare
  - pyroclastic flows
    - example: Mt. Pelee (Martinique), 1902-1903
    - example: more recently at Fuego (Guatemala), 2018



- Surtseyan Style
  - o violent explosions as magma contacts seawater or groundwater
  - o low, steam-enriched smaller columns
  - o forms "tuff cones" or "tuff rings"
  - o highly fragmented ash
    - example: Surtsey (Iceland), 1965
- Plinian Style
  - high eruption ash columns (can be into stratosphere)
  - o powerful, sustained eruptions
  - typically silicic compositions (dacite, rhyolite)
  - collapse of the column forms large pyroclastic flows
    - example: Vesuvius (Italy), A.D.
      79 & Pompeii



- Ultra-Plinian Style
  extremely high ash
  - columns (> 45 km)
  - eruption forms very large craters called calderas
  - occur on average every several 1000 years
    - example: last Yellowstone eruption
    - 70,000 years ago
    - has an average eruption cycle of ~ 70,000 years
  - there have been several caldera-forming eruptions in the western US over time

