Week 1 - Terrestrial Volcanism Overview

- Some definitions
- Eruption products
- Eruption triggers
- Eruption styles
- The role of water
- Where do volcanoes occur
- Monogenetic vs polygenetic
- Some volcano and eruption examples
**Volcanoes:**

Places where molten rock and gasses exit Earth’s (or another planet’s) surface

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**Volcanic construction materials**

Magma

molten or partially molten rock beneath the Earth’s surface. When magma erupts onto the surface, it is called lava, or cinders, ash, tephra or other pyroclasts

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Sketch by B. Myers

http://volcanoes.usgs.gov/Products/Pglossary/magma.html
Eruption Products

The relative proportion of these materials occur as a function of magma type, tectonic setting and local variables.

Eruption Triggering

Some important factors

- Tectonic triggers (changes in stress field)
- Tectonic setting (compressive or extensional)
- Vent opening (pressure increase from new magma input and/or gas exsolution)
- Vent plugging/clogging may promote flank eruptions
- Closed-system magma differentiation (pressure increase)
Eruption Styles

Important Magmatic factors

These work together to affect eruption style
- Viscosity
- Magma composition
- crystallinity
- gas content
- temperature
- pressure

Hot: Mafic (Magnesium and iron rich)

Cold: silicic (Silicon-dioxide rich)

Temperature vs. viscosity
Magmatic water vs. viscosity
Crystallinity vs. viscosity

Fig. 3. Relationship between viscosity and temperature for some volcanic rocks. The rocks were glassy or liquid through the entire temperature range. (Munro and McBirney, 1977)

Fig. 4. Effects of crystal content on the relative viscosity of a Hawaiian tholeiitic basalt (MLB) and a Mount St Helens dacite (SH). Relative viscosity \( n_p \) is defined as the ratio of the viscosity of the liquid-crystal suspension to that of the crystal-free liquid at the same temperature. Crystal content is given in terms of the volume fraction \( f \) of suspended crystals. Curves labeled U and L are calculated for plumes of silicic and mafic rocks, respectively. (McBirney & Munro, 1984)

Fig. 5. The effect of H2O on the viscosity of (a) granite and (b) basaltic melts at varying temperatures. (Munro, 1982)
Eruption Classifications

Related factors

- Effusive vs Explosive
- Dry vs Hydrovolcanic (internal vs. external gas source)
- Central vent vs Fissure eruption
- Eruption rate
- Submarine vs subaerial

Eruption Styles

<table>
<thead>
<tr>
<th>Magma composition</th>
<th>Effusive</th>
<th>Explosive</th>
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<tbody>
<tr>
<td>Mafic, but not always</td>
<td>Less</td>
<td>More</td>
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| Fragmentation | Lesser | More |
| Dispersal | | |
| Usual duration | Longer | shorter |

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<th>Column height</th>
<th>increasing</th>
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Increasing Column height

Increasing Magma composition
Water pressure also controls fragmentation
Viscosity and density of water control dispersal

Maximum explosivity at magma:water ~1

Various cycles of hydration/naturation displayed by several type of studied volcanoes. Temporal variations of water to magma mass ratios are shown for (1) Cotatlan, Mexico; (2) Kilauea Iki, Hawaii, (3) Penitente, Mexico; (4) Masaya, Nicaragua; (5) Turrialba, Costa Rica; (6) El Salvador, (7) Orizaba, Mexico; (8) Southern Oregon; (9) Kilauea, Hawaii; (10) Puu Oo, Hawaii; (11) Stromboli, Italy. These cycles cluster around the water to magma mass ratios shown in Fig. 6.
Koko Head and Hanauma Bay

Surtseyan, shallow submarine explosive

Tongatapu, 2009
Lava Meets the Sea from above

Littoral activity at Kilauea

Limu o Pele forming as the skin of a cooling lava bubble shell bursts at Puu Oo

Fluidal pyroclasts collected in the deep sea

Clague et al. 2009
**Water pressure effects**

Fig. 50. Relationship between depth of eruption below sea level, modal abundance of vesicles and density in tholeiitic basalt. (Moore and Schilling, 1973)

**Figure 12.** A. Photomicrograph of highly vesicular lava sample SS02-7/C (location shown in Figure 7) collected from a steep-sided cone during Shindai 6300 dive SS02. Image is 3.5 cm wide. Gtagie et al., 2002, North Arc of Hawaii, 4300m water depth

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**Bubble rich basalt scoria from the NELSC, 1700m water depth**
Subaqueous Column Height

Column height

Water depth/water pressure

What is the depth cut off for this process?

Currents and water density affect submarine plume behavior

Multiple wispy plumes caught right after a short duration eruption

Baker et al., 2011
NW Rota Seamount in 2006 …

Pyroclastic ejecta and a tiny bit of glowing red rock

Courtesy of NOAA Vents Program

Some submarine lava forms
Collapsed lobate lavas showing hollow interior

Seismometer stuck in a submarine jumbled sheet flow – Axial 1998

Hackly sheet flow and dead tubeworms – EPR

Curtain folded sheets NELSC 2008
Explosive submarine eruption at W. Mata Volcano, 1200m water depth
May 2009

Submarine strombolian eruption at W. Mata Volcano, 1200m water depth
May 2009
Vent-proximal lobate lavas, W. Mata Volcano
Note pyroclastic apron over the lavas
Where do we find Volcanoes?

Most of Earth’s volcanism occurs at convergent and divergent boundaries, plus intraplate hotspots.

Subduction zones

Ocean ridges

http://www.ngdc.noaa.gov/mgg/image/crustalimages.html

Crustal ages in the ocean basins today.

http://www.ngdc.noaa.gov/mgg/image/crustalimages.html
Volcano Type and Plate Tectonic Setting

- **Shield Volcano** – hotspots, especially oceanic
- **Stratovolcano** – convergent plate boundaries (subduction zones)
- **Cinder Cones, Tuff Rings, etc..** anywhere at or above sea level
- **Rift Volcano** – divergent plate boundaries (spreading centers)

Magma Type and Plate Tectonic Setting

- **Basalt through Rhyolite**, high volatile content
- **Tholeiitic + lesser alkalic basalt**, moderate volatile content
- **Basalt through Dacite**, usually relatively high volatile content
- **Usually restricted to basalt through andesite**
- **Usually restricted to basalt, low volatile content**
Monogenetic vs Polygenetic Volcanoes

Monogenetic: one eruption

Polygenetic: many eruptions

Subaerial Monogenetic Volcano Shapes

- shield
- cinder cone
- dome
- tuff ring
- mixed cone
Michoacán-Guanajuato Volcanic Field (Mexico)

El Jorullo 1759-1774 and Paricutin 1943-1952

Submarine Monogenetic?

Mata Volcanoes - Names and Summit Depths

Other photos: Ken Rubin

Photo: Jim Luhr
Subaerial Volcanoes come in 5 basic types plus hybrids.

Submarine volcanoes are similar, with arguably steeper sides

- Stratovolcano
- Rift Volcano
- Shield Volcano
- Pyroclastic cone
- Silicic Caldera

Rift Zone Volcano

Thingvallir, Iceland
Stratovolcano

Mayon Volcano, Philippines

Stratovolcanoes

St. Augustine, Alaska
http://volcanology.geol.ucsb.edu/volcano.htm

Shasta, California
http://www.peakware.com

Volcán Itztlixhuatl, Mexico
http://es.wikipedia.org/wiki/
Composite volcanoes

Hekla Volcano, Iceland

Shield Volcano

Mauna Loa, Hawaii – Earth's tallest and broadest volcano
usually calm, and steady …
Puu Oo eruption of Kilauea, Hawaii

some low spattering and fountaining
Puu Oo eruption of Kilauea, Hawaii
Halemaumau explosion

May 2009

http://hvo.wr.usgs.gov/kilauea/timeline/20090508_00345_L.jpg

1924 Kilauea summit explosion
Around 1,000-1,200 years ago, the largest explosion brought up rocks several kilometers (miles) from the volcano’s depths. This explosion was likely caused by rapid expansion of carbon dioxide bubbles within Kilauea’s deep plumbing system.

Cinder Cones

Pu’u ka Pele, Mauna Kea, Hawai’i
http://volcanoes.usgs.gov/Products/Pglossary/CinderCone.html

Hverfell, Krafla, Iceland
Photo by Ken Rubin

Red Hill, California
Tuff Cones and Rings

Koko Head and Crater, Hawaii

Diamond Head, Hawaii

Silicic Caldera

Silicic magma is gooey and cooler than other common types

Yellowstone Caldera, Western USA

Rhyolite tephra, Okataina New Zealand
lava domes

Panum dome (and crater), California  http://lvo.wr.usgs.gov/gallery/

Explosive Subaerial Eruptions

Pinatubo, Philippines, 1991
Explosive Submarine Eruptions

West Mata 2009