volcanism

- process that results in expulsion of molten rock on surface

lava and hot particles (pyroclasts) erupt and build volcanoes

examples:

- Mount Vesuvius
- Kilimanjaro
- Mt. Fuji
- Kilauea

in any given year about 50 eruptions occur

--about 600 volcanoes have erupted 200 times in past 2,000 years--
volcanism: benefits

atmosphere -- created from gases released by magmas

hydrosphere -- produced from condensation of water vapor released by volcanism

biosphere -- has positive and negative effects

• lava flows and ash weather to produce fertile soils
• violent eruptions can destroy nearly all life in their paths
• large amounts of ash and volcanic gases in atmosphere can trigger rapid climate changes and lead to mass extinctions

other benefits --

• added real estate
• geothermal energy
• spectacular scenery
living with volcanoes:

**mythology: Pele (Hawaii)**
exiled from Tahiti by her father because of her temper

**geothermal energy: Iceland**
source of inexpensive and clean energy
volcanic catastrophes: Pompeii, Tambora, Martinique, Nyos

Pompeii: 79 AD; Vesuvius

Tambora: 1815; 90,000 killed; larger than Krakatoa; year with no summer

Martinique: 1902; Pele

Lake Nyos: 1986; CO$_2$ gas released; hugged ground
not all volcanoes are the same!

contrast Mt. St. Helens with Hawaii

Why?

violence of eruptions controlled by:

- dissolved gases in the magma
  -- water vapor, carbon dioxide, sulfur dioxide, etc. and ease/difficulty by which they escape

- viscosity of the magma (fluid’s resistance to flow)
  -- silica content: higher silica has higher viscosity
  -- temperature: cooler lavas have higher viscosities
  -- dissolved gases: more dissolved gases yield lower viscosities
Pressure Effects on Volatile-rich Systems

From: Best, 2003
Volatile Control on Eruption Style

Explosive Volcanism
- Fragmentation
- Vesiculation: $z = 4$ km
- Conduit: $r \sim 50$ m
- Velocities: $v_{\text{conduit}} < v_{\text{eruptives}} < v_{\text{reservoir}}$
- Water Content: 4-5 wt % H$_2$O
- Surface Eruption: $z \sim 10$ km

Effusive Volcanism
- Degassing
- Vesiculation: $z \leq 1$ km
- Conduit: $r \sim 10$ m
- Water Content: $\sim 0.1$ wt % H$_2$O

From: Sparks, 1978
investigation of volcanism

rocks, gases, and events observed at modern eruptions are compared to similar ancient lavas to infer past activity

composition of rocks (silica content)

- **rhyolite**: high silica; light color
- **basalt**: low silica; dark color
- **andesite**: intermediate silica; intermediate color
extrusive textures

glassy: without mineral crystals

obsidian

fine-grained (aphanitic): crystals < 1 mm

basalt

porphyritic: large crystals in a matrix of small crystals

andesite
extrusive textures

**vesicular:** frothy (trapped gas bubbles)

**fragmental:** particles blasted apart by eruption

- dust and ash ( < 2 mm)
- cinders ( 2 – 64 mm)
- blocks and bombs ( > 64 mm)

**pyroclasts -- hot particles**

- *pumice*
- *cinder cone*
obsidian

Photo by C. C. Plummer
andesite (porphyritic)
andesite under microscope: note small/big crystals
vesicular basalt

vesicles represent gas bubbles
pumice (frothy)
volcanic bombs:
rapidly cooled magma thrown from vent
**Tuff**: rock composed of fine-grained pyroclastic material

Photo by C. C. Plummer
tuff
volcanic landforms

**vent:** opening through which lava erupts

**crater:** depression over the vent at the summit of the volcano

**caldera:** depression much larger than original crater ( > 1 km)
Cascade volcanoes

volcanic chain in Pacific Northwest from northern California to British Columbia

last major eruption was Mount Saint Helens in 1980 (andesitic) renewed dome growth in October 2004
Gary Rosenquist Photo Sequence -
Mt. St. Helen’s, May 18, 1980
(occurred in three minutes)
Mt. St. Helen’s eruption column – May 18, 1980

from: USGS http://vulcan.wr.usgs.gov/
eruption cloud in first 13 minutes

thickness of ash in cm
Mt. St. Helen’s
May 18, 1980
devastation
volcano after May 18, 1980
with lava dome inside crater

From: USGS http://vulcan.wr.usgs.gov/
what happened at Mt. St. Helens?

landslide “uncorked” magma chamber, removing load and causing eruption
characteristics of Mt. St. Helens?

- andesitic (intermediate silica)
- dome-forming: magma too viscous to flow from crater and solidifies at vent
- generated volcanic mudflows

*can lead to culminating explosions and caldera formation*
what is a caldera?

large depression ( > 1 km diameter) at top of volcano

sometimes they fill with water
Crater Lake and Wizard Island, Oregon
caldera formation from eruption of ancient Mt. Mazama

- Eruption begins
- Eruption expels large volumes of magma
- Ground collapses into empty chamber
- Steam explosions produce water
map that shows features inside lake

volcanic cones
landslide
caldera formation associated with large eruptions

thickness of ash from Mt. Mazama eruption
Cascade Eruptions During The Past 4,000 Years

- Baker
- Glacier Pk.
- Rainier
- St. Helens
- Adams
- Hood
- Jefferson
- Three Sisters
- Newberry
- Crater Lake
- Medicine Lake
- Shasta
- Lassen

Years Ago

4000

2000

0

maximum extent of Bishop Tuff (ash produced)

another caldera-forming eruption (700,000 years ago)
yet another...Yellowstone (630,000 and 2,000,000 years ago)
VEI Redux

NB: Volumes are DRE (dense rock equivalent)

Source: USGS
example of ash
(not from Yellowstone)

Montserrat 2003
Mt. St. Helens, Vesuvius, Pele, most caldera collapses... produce **pyroclastic eruptions**

**viscous, gas-rich magma**

**pyroclasts** --
pyro: “fire”
clasts: “pieces”

hot dome collapses, producing **pyroclastic flows**

particles ejected into atmosphere and fall back, generating **pyroclastic flows**

Mt. Pinatubo, Phillipines
devastation of St. Pierre, Martinique by pyroclastic flows

over 30,000 killed; 1 survivor

1902
the capital city had to be rebuilt
## Deadliest Eruptions Since 1500 AD

<table>
<thead>
<tr>
<th>Eruption</th>
<th>Year</th>
<th>Casualties</th>
<th>Major Cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nevado del Ruiz, Colombia</td>
<td>1985</td>
<td>25,000</td>
<td>Mudflows</td>
</tr>
<tr>
<td>Mont Pelée, Martinique</td>
<td>1902</td>
<td>30,000 (29,025)</td>
<td>Pyroclastic flows</td>
</tr>
<tr>
<td>Krakatau, Indonesia</td>
<td>1883</td>
<td>36,000 (36,417)</td>
<td>Tsunami</td>
</tr>
<tr>
<td>Tambora, Indonesia</td>
<td>1815</td>
<td>92,000</td>
<td>Starvation</td>
</tr>
<tr>
<td>Unzen, Japan</td>
<td>1792</td>
<td>15,000 (14,030)</td>
<td>Volcano collapse, Tsunami</td>
</tr>
<tr>
<td>Lakagigar (Laki), Iceland</td>
<td>1783</td>
<td>9,000 (9,350)</td>
<td>Starvation</td>
</tr>
<tr>
<td>Kelut, Indonesia</td>
<td>1586</td>
<td>10,000</td>
<td></td>
</tr>
</tbody>
</table>
Eruption Frequency vs. VEI

Similar frequency-magnitude behavior as observed for earthquakes.

Volcanic Deaths by Country
Total = 238,000

Source: O. Melnik, Bristol