CEE 437: Volcanoes and Volcanic Hazards

A mountain formed by the accumulation of erupted material that is composed of extrusive igneous rock (volcanic material). This molten rock solidifies quickly; rapid cooling results in a fine grain size or absence of grains (amorphous, glass).

Extruded materials

Volcano Locations

Volcano Types

Web Resources
http://www.volcanoworld.org
http://vulcan.wr.usgs.gov
Volcanic Rock Types

<table>
<thead>
<tr>
<th>Lava Type</th>
<th>SiO2</th>
<th>Fe-Mg</th>
<th>Extrusive</th>
<th>Intrusive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicic</td>
<td>~70%</td>
<td>~5%</td>
<td>Rhyolite</td>
<td>Granite</td>
</tr>
<tr>
<td>Intermediate</td>
<td>~60%</td>
<td>~10%</td>
<td>Andesite</td>
<td>Diorite</td>
</tr>
<tr>
<td>Mafic</td>
<td>~50%</td>
<td>~20%</td>
<td>Basalt</td>
<td>Gabbro</td>
</tr>
</tbody>
</table>
Lava - a liquid flow of magma on the earth's surface:

- Can form lava lakes, fountains, or lava falls.
- Mobilized lava flows will burn and bury everything in their path (up to 1,100 °C).
- Can sometimes be redirected (constructed trenches, explosions, or water-chilled).
Pyroclastic material - "fire broken" - chunks of airborne ejected magma (tephra) that cool quickly.

Ashfalls: ash carried by wind can be deposited hundreds of miles away from the volcano.

Ash and dust can also enter the upper atmosphere and affect climate.

Buried the ancient city of Pompeii, 79 A.D. (Mount Vesuvius).
Volcanic ash can cause internal-combustion engines to stall by clogging air filters and also damage the moving parts of vehicles and machinery, including bearings and gears. Engines of jet aircraft have suddenly failed after flying through clouds of even thinly dispersed ash. Roads, highways, and airport runways can be made treacherous or impassable because ash is slippery and may reduce visibility to near zero. Cars driving faster than 5 miles per hour on ash-covered roads stir up thick clouds of ash, reducing visibility and causing accidents.

Ash also clogs filters used in air-ventilation systems to the point that airflow often stops completely, causing equipment to overheat. Such filters may even collapse from the added weight of ash, allowing ash to invade buildings and damage computers and other equipment cooled by circulating outside air. Agriculture can also be affected by volcanic ash fall. Crop damage can range from negligible to severe, depending on the thickness of ash, type and maturity of plants, and timing of subsequent rainfall. For farm animals, especially grazing livestock, ash can lead to health effects, including dehydration, starvation, and poisoning.

Like airborne particles from duststorms, forest fires, and air pollution, volcanic ash poses a health risk, especially to children, the elderly, and people with cardiac or respiratory conditions, such as asthma, chronic bronchitis, and emphysema.

The best time for communities, businesses, and homeowners to make preparations for a rain of volcanic ash is before an eruption occurs. When an explosive eruption does occur, warning of advancing ash clouds may precede actual ash fall by only minutes or hours. By developing community emergency-response plans that can be activated when a volcano is threatening to erupt, the harmful and disruptive effects of ash can be greatly reduced. So that the public can be warned of impending eruptions and advancing ash clouds, the U.S. Geological Survey (USGS) and cooperating organizations operate instrument networks that monitor more than 40 active volcanoes in the United States.

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COOPERATING ORGANIZATIONS
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National Oceanic and Atmospheric Administration, National Weather Service

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U.S. Geological Survey Volcano Hazards Program
http://volcanoes.usgs.gov/

See also What are Volcano Hazards? (USGS Fact Sheet 002-97) and Volcanic Ash—Danger to Aircraft in the North Pacific (USGS Fact Sheet 003-97)
Ashflows: turbulent mixtures of gases and pyroclastic material

often the result of the collapse of a vertical column ejected upward from the volcano.

Can move very quickly downhill (up to 100 mph) and are extremely deadly (very hot and powerful)

Also known as a nuée ardente (French for glowing cloud)

One such flow killed over 30,000 people in 1902 (Martinique, West Indies, Mount Pelée)
GAS: Carbon dioxide, hydrogen sulfide and other gases are emitted from magma chambers. The gases can be fatal to plants and animals. Tree kill example below from Long Valley Caldera, Mammoth Mountain, CA
**Debris flows**: Water from heavy precipitation, melted snow or streams may help mobilize pyroclastic material (rocks, ash, and cinders) into a fast-moving debris flow (also called a *lahar* - Indonesian word).

Sometimes, only a minor eruption is necessary, just need to mobilize a lot of material.

Buried the village of Armero in Colombia, 1985, with a wall of mud 130 feet high.

Predicted hazards from lahars in the region surrounding Mount Rainier (visible from Seattle): 100,000 people living on volcanic deposits less than 10,000 years old
Extent of Two Holocene Mudflows from Mount Rainier

OSCEOLA MUDFLOW
(~ 5000 years old)

ELECTRON MUDFLOW
(~ 500 years old)

Mount Rainier

References:
Topinka, USGS/CVO, 1997; Modified from: Cranek, et al., 1979
Post-5,600-year-old lava cone and crater
Buried edge of 5,600-year-old collapse crater

Little Tahoma Peak
Steamboat Prow
Emmons Glacier
1963 debris avalanche
White River Valley
Sunrise Visitor Center
West Side of Mt Rainier, Sunset Amphitheater, source of Electron Mudflow
Figure 1. Representative AVIRIS spectra of alteration subtypes. "A", clay-rich argillic alteration; "B", silica-rich argillic alteration; "C", Fe-oxide-rich alteration; "D", Chlorite alteration; "E", sericite alteration. Arrowed spectral features are discussed in the text.
Locations of Volcanos: 80% of world’s volcanoes are in the Ring of Fire
As is apparent from Figure 3.29, a stock may merely be a companion body to a batholith or even the top of a partly eroded batholith.

**FIGURE 3.31** The Idaho, Sierra Nevada, and Southern California batholiths, largest in the conterminous United States, are dwarfed by the Coast Range Batholith in southern Alaska and British Columbia. Each of these giant batholiths formed from magma generated by the partial melting of continental crust, and each intrudes metamorphosed rocks.
Non-subduction related volcanism is called **intraplate**

- An intraplate volcano is usually linked to a **hot spot** - a region of thin crust where hot material from deep in the earth (lower mantle or near the core) pokes through the crust.

- Examples include the Hawaiian Islands (plate movement over a stationary hot spot) and Yellowstone National Park.
Nature of volcanic eruptions

- **Explosive eruption** requires a very viscous magma (viscosity describes the resistance to flow, related to silica content - SiO₂) and a lot of gas (mainly CO₂ and water vapor).
- A highly viscous magma is very sticky and holds in all of the gases, non-viscous lava is runny and low in gas.
- Once the pressure is relieved as the magma reaches the earth's surface, the gas is released violently (like champagne).

<table>
<thead>
<tr>
<th>Eruptive Style</th>
<th>Erupted Material</th>
<th>Volcano Type</th>
<th>Tectonic Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Explosive</td>
<td>Basalt (mafic) lava flows</td>
<td>Shield Volcano</td>
<td>Hot Spot or Divergent</td>
</tr>
<tr>
<td>Explosive</td>
<td>Andesite and Rhyolite (felsic) lava Pumice, ash, dust, and other pyroclastic material</td>
<td>Stratovolcano (composite) Also cinder cone, lava dome, or caldera</td>
<td>Convergent (subduction zones beneath islands and continents)</td>
</tr>
</tbody>
</table>
## Types of Volcanoes

<table>
<thead>
<tr>
<th>Volcano Type</th>
<th>Characteristics</th>
<th>Examples</th>
<th>Simplified Diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood or Plateau Basalt</td>
<td>Very liquid lava; flows very widespread; emitted from fractures</td>
<td>Columbia River Plateau</td>
<td><img src="image1" alt="Diagram" /></td>
</tr>
<tr>
<td>Shield Volcano</td>
<td>Liquid lava emitted from a central vent; large; sometimes has a collapse caldera</td>
<td>Larch Mountain, Mount Sylvania, Highland Butte, Hawaiian volcanoes</td>
<td><img src="image2" alt="Diagram" /></td>
</tr>
<tr>
<td>Cinder Cone</td>
<td>Explosive liquid lava; small; emitted from a central vent; if continued long enough, may build up a shield volcano</td>
<td>Mount Tabor, Mount Zion, Chamberlain Hill, Pilot Butte, Lava Butte, Craters of the Moon</td>
<td><img src="image3" alt="Diagram" /></td>
</tr>
<tr>
<td>Composite or Stratovolcano</td>
<td>More viscous lavas, much explosive (pyroclastic) debris; large, emitted from a central vent</td>
<td>Mount Baker, Mount Rainier, Mount St. Helens, Mount Hood, Mount Shasta</td>
<td><img src="image4" alt="Diagram" /></td>
</tr>
<tr>
<td>Volcanic Dome</td>
<td>Very viscous lava, relatively small; can be explosive; commonly occurs adjacent to craters of composite volcanoes</td>
<td>Novarupta, Mount St. Helens Lava Dome, Mount Lassen, Shastina, Mono Craters</td>
<td><img src="image5" alt="Diagram" /></td>
</tr>
<tr>
<td>Caldera</td>
<td>Very large composite volcano collapsed after an explosive period; frequently associated with plug domes</td>
<td>Crater Lake, Newberry, Kilauea, Long Valley, Medicine Lake, Yellowstone</td>
<td><img src="image6" alt="Diagram" /></td>
</tr>
</tbody>
</table>

*Topinka, USGS/ICV, 1997. Modified from Allen, 1975, Volcanoes of the Portland Area, Oregon, Ore-Bin, v.37, no.9*
**Shield volcano** - broad, gently sloping volcano - looks like a warrior's shield laying down (Hawaii)
**Stratovolcano (Composite)** - combined explosive eruptions of lava and ash (viscous) form a steep-sided volcano.
Cinder cone - all pyroclastic material (no lava), small cones that quickly erode. Example: Paricutín, Mexico
**Lava Dome** - very viscous lava piles up around a volcanic vent and forms a bulbous plug.

- Has the potential for a very violent eruption.
- Often form inside the crater of a larger stratovolcano. (Mt. St. Helens, fills 4% of crater)
- Example - Mt. Pelée, Martinique, Caribbean.
**Caldera** - extremely violent eruptions that produce a huge crater (10's of km across).

- eruptions are so violent (VEI ~6) that the top of the volcano is blown off
- when the magma chamber empties, the large underground chamber collapses.
- Example - Yellowstone (multiple calderas, still geothermally active).
- Example - Crater Lake (Oregon) - Formerly Mt. Mazama (VEI 7 eruption 4895 B.C.)
Crater Lake Caldera, Oregon

Caldera – a large depression generally caused by the removal of large quantities of magma from beneath a volcano, causing the ground to "collapse" into the emptied space

Wizard Island – a "volcano within a volcano" – a small cinder cone rising nearly 2,400 feet above the lake bottom

X

approximate location of Crater Lake's deepest spot – 1,932 feet

nearly 7,000 years ago Mount Mazama volcano erupted, sending ash as far east as Nebraska, and creating the nearly 6-mile-wide depression now filled by Crater Lake
Flood Basalts or Fissures Eruptions
Volume, cumulative percent

Age, millions of years

Imnaha (9,500)

Wanapum (10,800)

Saddle Mountains (2,400)

Grande Ronde (148,700)

and

Picture Gorge (3,000)
Along the banks of the Columbia River - basalt cliffs near Lyle, Washington.