Module 3  Volcanoes

Image courtesy of USGS.
Natural phenomenon

Natural hazard
The notion of hazard requires human presence (in the wrong place)

Image courtesy of USGS.
Natural hazard

\[\downarrow\]

Natural catastrophe
Armero (Nevado del Ruiz) - Nov 13, 1985

23,000 fatalities; 5000 injured; $7,700M damage

Image courtesy of USGS.
Volcanoes

introduction
Volcanoes

**definition 1:** a vent in the crust of the earth or another planet through which lava, rock fragments, hot vapor, and gases erupt

**definition 2:** a mountain formed by volcanic material
Volcanoes

**MAGMA:** molten rock inside the earth

**LAVA:** magma that erupts at the Earth’s surface

**PYROCLAST:** all solid fragments ejected from volcanoes

**TEPHRA:** all pyroclasts that fall to the ground from eruption columns
Volcanic environments

Image courtesy of USGS.
- **active volcanoes**: have erupted in the last 10,000 yr and still have the potential to erupt (~1500 active volcanoes; ~60 eruptions per year; ~20 eruptions at any given time)

- **dormant volcanoes**: have not erupted in the last 10,000 yr but still have the potential to erupt

- **extinct volcanoes**: have “no chance” of ever erupting again
Distribution of volcanoes

- Spreading ridge volcanism: ~75%
- Subduction zone volcanism: ~15%
- Intraplate volcanism: ~10%

Image courtesy of USGS.
Distribution of volcanoes

Image courtesy of NOAA.
Melting rocks in the earth

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Please see “Melting rocks in the earth” in:
Melting rocks in the earth

peridotite

Image courtesy of NASA.
Melting rocks in the earth

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Please see “Melting rocks in the earth” in:
Melting at spreading ridge

Image courtesy of NOAA.
Melting at spreading ridge

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Please see “Melting at spreading ridge” in:
Melting at subduction zones

Image courtesy of NOAA.
Melting at subduction zones

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Melting at subduction zones

Image courtesy of USGS.
Intraplate magmatism

Image courtesy of NOAA.
Types of volcanic eruptions

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Please see:
Hawaiian eruption

basaltic eruption with very low viscosity magma (10-100 Pa s), comprising lava fountains and lava flows

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Please see:
http://www.firstscience.com/images/articles/self/flow.jpg
Strombolian eruption

basaltic eruption with low viscosity magma (100-1000 Pa s), comprising lava fountains and lava flows and series of explosions

Image courtesy of USGS.
Vulcanian eruption

small to moderate-sized volcanic outbursts that eject material to heights <20km and last on the order of seconds to minutes
Plinian eruption

large, explosive events that form enormous dark columns of tephra and gas high into the stratosphere (>20km)

Image courtesy of USGS.
Surtseyan eruption

violent explosions caused by rising basaltic magma that come into contact with abundant surface water (or shallow groundwater)

Image courtesy of NOAA.
Types of volcanic eruptions

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Please see:
Volcanic intensity

Image courtesy of USGS.
## 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="image" 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="image" 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="image" 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="image" 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="image" 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="image" alt="Diagram" /></td>
</tr>
</tbody>
</table>

Image courtesy of USGS.

Topinka, USGS/CVD, 1997; Modified from: Allen, 1975, Volcanoes of the Portland Area, Oregon, Ore-Bin, v.37, no.9
fissure

**definition:** elongate fracture or crack at the surface from which lava erupts

**common environments:** spreading ridges and intraplate

**photo:** flank of Kilauea, Hawaii
Cinder cone

**definition:** steep, conical hill of volcanic fragments that accumulate around and downwind from a vent

**common environments:** various

**photo:** flank of Mauna Kea, Hawaii

Image courtesy of USGS.
Shield volcano

definition: Volcanoes with broad, gentle slopes and built by the eruption of fluid basalt lava
common environments: various (esp. spreading ridges and intraplate)
photo: Mauna Loa, Hawaii

Image courtesy of USGS.
Stratovolcano (composite)

**Definition:** steep, conical volcano built by the eruption of viscous lava flows, tephra, and pyroclastic flows

**Common environments:** subduction zones

**Photo:** Rainier, WA

Image courtesy of USGS.
Volcanic (lava) dome

**definition:** rounded, steep-sided mounds built by very viscous magma

**common environments:** subduction zones

**photo:** Novarupta vent, Valley of Ten Thousand Smokes, Alaska
**Caldera**

**definition:** large, usually circular depression at the summit of a volcano formed when magma is withdrawn or erupted from a shallow underground magma reservoir

**common environments:** various

**photo:** Aniakchak Caldera, Alaska

Image courtesy of USGS.
Volcanic hazards

direct hazards:
- tephra and ballistic projectiles
- pyroclastic flows/surges
- lateral directed blasts
- debris avalanches
- debris flows/lahars, floods
- lava flows
- earthquakes

Image courtesy of USGS.
Volcanic hazards

indirect hazards:
- tsunami
- debris flows/lahars, floods
- air pollution
- post-eruption famine and disease
- aerosols and global atmospheric effects
- aircraft encounters with volcanic ash
- biotic extinctions (?)

Image courtesy of USGS.
# Volcanoes as a hazard

<table>
<thead>
<tr>
<th>Type of Hazard</th>
<th>No of Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drought</td>
<td>782</td>
</tr>
<tr>
<td>Earthquake</td>
<td>899</td>
</tr>
<tr>
<td>Extreme temperature</td>
<td>240</td>
</tr>
<tr>
<td>Famine</td>
<td>77</td>
</tr>
<tr>
<td>Flood</td>
<td>2389</td>
</tr>
<tr>
<td>Landslide</td>
<td>448</td>
</tr>
<tr>
<td>Strom surge</td>
<td>18</td>
</tr>
<tr>
<td>Tornadoes (non-US)</td>
<td>84</td>
</tr>
<tr>
<td>Tornadoes (US)*</td>
<td>9476</td>
</tr>
<tr>
<td>Tsunami</td>
<td>986</td>
</tr>
<tr>
<td>Tropical cyclone</td>
<td>1337</td>
</tr>
<tr>
<td>Volcano</td>
<td>168</td>
</tr>
<tr>
<td>Wind (other)</td>
<td>793</td>
</tr>
<tr>
<td>Wild fire</td>
<td>269</td>
</tr>
</tbody>
</table>

*for F2-F5 Tornadoes 1950 - 995

Figure by MIT OpenCourseWare.

Bryant, 2005
## Volcanoes as a hazard

<table>
<thead>
<tr>
<th>Type of Hazard</th>
<th>Deaths</th>
<th>Injuries</th>
<th>Homeless</th>
<th>Largest Death Toll Event and Date</th>
<th>Death Toll</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avalanches, Landslides, Mud flows</td>
<td>60,501</td>
<td>8,071</td>
<td>3,759,329</td>
<td>Soviet Union, 1949</td>
<td>12,000</td>
</tr>
<tr>
<td>Cold wave</td>
<td>6,807</td>
<td>1,307</td>
<td>17,340</td>
<td>India, Dec 1982</td>
<td>400</td>
</tr>
<tr>
<td>Extra-tropical storms</td>
<td>36,681</td>
<td>117,925</td>
<td>12,606,891</td>
<td>Northen Europe, Feb 1953</td>
<td>4,000</td>
</tr>
<tr>
<td>Earthquakes</td>
<td>1,846,119</td>
<td>1,147,676</td>
<td>8,953,296</td>
<td>Tangshan, China, July 1976</td>
<td>242,000</td>
</tr>
<tr>
<td>Fires</td>
<td>2,503</td>
<td>1,658</td>
<td>140,776</td>
<td>USA, Oct 1918</td>
<td>1,000</td>
</tr>
<tr>
<td>Floods</td>
<td>6,851,740</td>
<td>1,033,572</td>
<td>123,009,662</td>
<td>China, July 1931</td>
<td>3,700,000</td>
</tr>
<tr>
<td>Heat wave</td>
<td>14,732</td>
<td>1,364</td>
<td>0</td>
<td>India, May 1998</td>
<td>2,541</td>
</tr>
<tr>
<td>Tornado</td>
<td>7,917</td>
<td>27,887</td>
<td>575,511</td>
<td>Bangladesh, Apr 1989</td>
<td>800</td>
</tr>
<tr>
<td>Tsunami</td>
<td>10,754</td>
<td>789</td>
<td>-</td>
<td>Sanriku Japan, Mar 1933</td>
<td>3,000</td>
</tr>
<tr>
<td>Tropical cyclones</td>
<td>1,147,877</td>
<td>906,311</td>
<td>34,272,470</td>
<td>Bangladesh, Nov 1970</td>
<td>300,000</td>
</tr>
<tr>
<td>Volcano</td>
<td>96,770</td>
<td>11,154</td>
<td>197,790</td>
<td>Martinique, May 1902</td>
<td>30,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>10,052,401</strong></td>
<td><strong>3,257,714</strong></td>
<td><strong>183,533,065</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure by MIT OpenCourseWare.

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### Volcanoes as a hazard

<table>
<thead>
<tr>
<th>Type</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold wave</td>
<td>$9,555,000,000</td>
</tr>
<tr>
<td>Drought</td>
<td>$16,800,000,000</td>
</tr>
<tr>
<td>Earthquake</td>
<td>$248,624,900,000</td>
</tr>
<tr>
<td>Flood</td>
<td>$206,639,800,000</td>
</tr>
<tr>
<td>Heat wave</td>
<td>$5,450,000,000</td>
</tr>
<tr>
<td>Tropical storm</td>
<td>$80,077,700,000</td>
</tr>
<tr>
<td>Wild fire</td>
<td>$20,212,800,000</td>
</tr>
<tr>
<td>Wind storm</td>
<td>$43,890,000,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$631,250,200,000</strong></td>
</tr>
</tbody>
</table>

Figure by MIT OpenCourseWare.

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