Volcanoes:

• Windows into Earth’s interior
• Help us understand plate tectonic process and mantle convection
  • At present, but also millions to billions of years in past using radioisotopic dating
• Impact Earth’s atmosphere and hydrosphere
• Pose hazards to millions of people
Volcanic geosystem

Lithosphere

Pipe

Central vent

Lava flows

Dike

Sill

Magma chamber

Lava eruptions

...rises through the lithosphere to form a crustal magma chamber.

Magma, which originates in the asthenosphere...

Gases injected into atmosphere (H₂O, CO₂, SO₄).

...accumulating on the surface to form a volcano.

Lavas erupt through a central vent and side vents,...

Lavas and other volcanic deposits

• Types of lava
  • Basaltic (1000-1200° C)
• Andesitic-dacitic (800-1000º C)

Volcán Licancabur, Northern Chilean Andes

• Rhyolitic (600-800º C)

May 24, 1960 rhyolite (obsidian) flow, Volcán Puyehue, Southern Chilean Andes
• **Textures**
  - Aphantic (glassy)-Porphyritic (few crystals)
  - Vesicular (bubbles)
  - Pyroclastic (fragmental)
    - Ash, lapilli, bombs (falls)
    - Pyroclastic flows (tuffs)

Why the contrast in explosivity?

**Composition**

**Basalt**
- Isolated SiO$_4$
- High T (1100°C)
- Low viscosity
- Water diffuses out of melt
- Thus weak explosivity

**Dacite**
- Framework SiO$_4$
- Low T (700°C)
- High viscosity
- Water trapped in melt
- Bubbles form, expand as magma rises, decompresses until!

Arenal, Costa Rica
Strombolian eruption
Basaltic bombs coalesce and flow

Mt. Unzen, Japan
Dacitic dome collapse
Pyroclastic ash flow
Pyroclastic Flows


a. Collapse of a vertical explosive or plinian column that falls back to earth, and continues to travel along the ground surface.
b. Lateral blast, such as occurred at Mt. St. Helens in 1980.
c. “Boiling-over” of a highly gas-charged magma from a vent.
d. Gravitational collapse of a hot dome.

(from Winter (2001))

Volcán Lascar, Northern Chile -1993 pyroclastic flow (dacite) primarily ash and bombs
Eruptive styles and landforms

- shield volcanoes
- volcanic domes
- cinder-cone volcanoes
- stratovolcanoes
- volcanic craters (ash flow tuff)
- calderas (ash flow tuff)
- diatremes
- fissure eruptions (flood basalt)

**Shield volcanoes** are built up by the accumulation of thousands of thin basaltic flows that spread as gently sloping sheets. Each layer in the diagram represents many hundreds of thin flows. Magma can erupt on the flanks of a volcano as well as from the central vent.
Mauna Loa (Hawaii)

Volcanic domes are bulbous masses of felsic lava, which are so viscous that instead of flowing, they pile up over the vent. The photo shows a growing dome within the crater of Mount St. Helens after its 1980 eruption.
Cinder-cone volcanoes are formed when ejected material is deposited as layers that dip away from the crater at the summit. The vent beneath the crater is filled with fragmental debris. The photo is of Cerro Negro, shown erupting in 1968, a cinder cone built on an older terrain of lava flows.
February 25, 1943. Day 5 of Paricutin Volcano’s first lava flow. Note eruption of scoria from atop 200 m high cinder cone.

Stratovolcanoes are built from alternating layers of pyroclastic material and lava flows. Lava that has solidified in fissures forms ribbonlike dikes that strengthen the cone.
Craters are found at the summits of most volcanoes. After an eruption, lava often sinks back into the vent and solidifies, to be blasted out by a later pyroclastic explosion.

**Volcán Puyehue, southern Chilean Andes**

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**Crater Lake (Oregon)**

**Caldera formation**

**STAGE 1**
Fresh magma fills a magma chamber and triggers a volcanic eruption of lava and columns of incandescent ash.

**STAGE 2**
Eruption of lava and pyroclastic flows continue, and the magma chamber becomes partly depleted.

**STAGE 3**
A caldera results when the mountain summit collapses into the empty chamber. Large pyroclastic flows accompany the collapse, blanketing the caldera and a surrounding area of hundreds of square kilometers.

**STAGE 4**
A lake forms in the caldera. As the residual magma in the chamber cools, minor eruptive activity continues in the form of hot springs and gas emissions. A small volcanic cone forms in the caldera.
• Crater Lake Caldera
• Mt. Mazama ash
  – 50 km³
  – Erupted 6950 yrBP

Figure 4. Approximate aerial extent and thickness of Mt. Mazama (Crater Lake) ash fall, erupted 6950 years ago. After Young (1990), Unpubl. Ph.D. thesis, University of Lancaster, UK.

from Winter (2001)

Long Valley Caldera, California
• Bishop Tuff (>100 m thick)
• non-welded base
• welded interior
welding and compaction in ash flow tuff = flattened pumice lapilli

Laki fissure eruption
Iceland

1. Highly fluid basalt erupting from fissures...
2. ...forms widespread layers rather than mountains.
Impacts of volcanism
• hydrosphere
• atmosphere

Fumaroles, Santiaguito dome
Guatemala

Old Faithful geyser, Yellowstone
Benefits of volcanism: geothermal energy

Global pattern of volcanism
large igneous provinces

1. Instability at the core-mantle boundary causes a mantle plume to arise, led by a hot, turbulent plume head.

2. When the plume reaches the top of the mantle, basaltic magma from decompression melting penetrates the lithosphere and erupts as flood basalts.

3. As the plate moves over remnants of the plume, the plume tail—now a hot spot—may form a hot-spot volcanic chain.

4. Continued plate movement over the hot spot creates a hot-spot volcanic chain.

Figure 12.25
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Volcanism and human affairs

**Hazards**
- lahars
- flank collapse
- caldera collapse
- eruption clouds

**Resources**
- volcanic soils
- industrial materials
- ore formation
- geothermal energy

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**Volcanism and human affairs**

![Graph showing cumulative fatalities due to volcanic eruptions from 1500 to 2000 AD. Key volcanic events include:
- Kelut 1586
- Laki 1783
- Unzen 1792
- Krakatoa 1883
- Tambora 1815
- Pelée 1902
- Ruiz 1985

The graph illustrates the cumulative fatalities, with numbers representing thousands of deaths.**