Introduction to Environmental Geology, 5e

Chapter 8

Volcanic Activity

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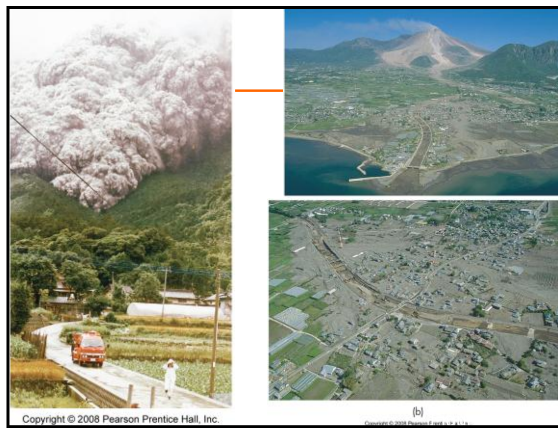
Chapter 8: Overview

- Know the major volcano types, their rocks, and plate tectonic settings
- Understand the effects of volcanic activity:
  - Lava flows
  - Pyroclastic activity
  - Debris flows and mudflows (lahars)
- Understand the methods of volcanic activity monitoring

Case History: Mt. Unzen, 1991

- One of the 19 active volcanoes in Japan
- Erupted and killed approximately 15,000 people 200 years ago
- Erupted violently on June 3, 1991
- Thousands of ash flows by the end of 1993, getting the dubious honor of the king of the ash flow centers
- 44 people killed, including Harry Glicken, a U.S. volcanologist who escaped death in the May 18, 1980 eruption of Mount St. Helens



Introduction to Volcanic Hazards

- ~ 1,500 active volcanoes on Earth
- 400 erupted in the last century
- ~ 50 eruptions per year
- Most activity concentrated along major plate boundaries
- Impact risks depend on the types of volcanoes

Introduction to Volcanic Hazards

- ~ 500 million people living near volcanoes
- ~ 100,000 deaths during the last 125 years
- 23,000 lives lost in the last 20 years
- Densely populated countries in the volcanic zones include:
  - Japan, Mexico, Philippines, and Indonesia
- Some major cities (~ 350,000 people) located near volcanoes

TABLE 8.1 Selected Historic Volcanic Events

Volcano or City	Year	Effect
Vesuvius, Italy	A.D. 79	Destroyed Pompeii and killed 16,000 people. City was buried by volcanic activity and rediscovered in 1595.
Skaptar Jokull, Iceland	1783	Killed 10,000 people (many died from famine) and most of the island's livestock. Also killed some crops as far away as Scotland.
Tambora, Indonesia	1815	Caused global cooling; killed 10,000 people and 80,000 starved; produced "year without a summer."
Krakatau, Indonesia	1883	Tremendous explosion; more than 36,000 deaths from tsunami.
Mount Pelée, Martinique	1902	Ash flow killed 30,000 people in a matter of minutes.
La Soufrière, St. Vincent	1902	Killed 2,000 people and caused the extinction of the Carib Indians.
Mount Lamington, Papua New Guinea	1951	Killed 6,000 people.
Villarica, Chile	1963–1964	Forced 30,000 people to evacuate their homes.
Mount Helgafell, Heimaey Island, Iceland	1973	Forced 5,200 people to evacuate their homes.
Mount St. Helens, Washington, United States	1980	Debris avalanche, lateral blast, and mudflows killed 57 people and destroyed more than 100 homes.
Nevado del Ruiz, Colombia	1985	Eruption generated mudflows that killed at least 22,000 people.
Mount Unzen, Japan	1991	Ash flows and other activity killed 41 people and burned more than 125 homes. More than 10,000 people evacuated.
Mount Pinatubo, Philippines	1991	Tremendous explosions, ash flows, and mudflows combined with a typhoon killed more than 740 people; several thousand people evacuated.
Montserrat, Caribbean	1995	Involved explosive eruptions, pyroclastic flows; south side of island evacuated, including capital city of Plymouth; several hundred homes destroyed.
Mount Nyiragongo, Congo, Africa	2002	Involved lava flows through 14 villages and part of the city of Goma; several hundred thousand people evacuated, about 5,000 homes destroyed, and about 45 people killed.
Chaitén, Chile	2008	Involved explosive eruptions, pyroclastic flows; 5,000 people evacuated; disrupted aviation in South America for weeks.
Eyjafjallajokull, Iceland	2010	Large ash emission disrupted air travel in the United Kingdom and northern Europe for several weeks. Over 95,000 flights were canceled and losses to airlines exceeded $1 billion.
Mount Merapi, Indonesia	2010	Involved explosions and pyroclastic flows; 200,000 people evacuated and over 150 deaths.

Data partially derived from Ollier, C. 1969. Volcanoes. Cambridge, MA: MIT Press.

Table 8.1

Introduction to Volcanic Hazards

- Highly related to plate tectonic movement
- Approximately 2/3[rd] of the active volcanoes are concentrated along the Pacific "*ring of fire*"
- In the US: Alaska, Cascades, and Hawaii are generally experiencing 2-3 eruptions a year

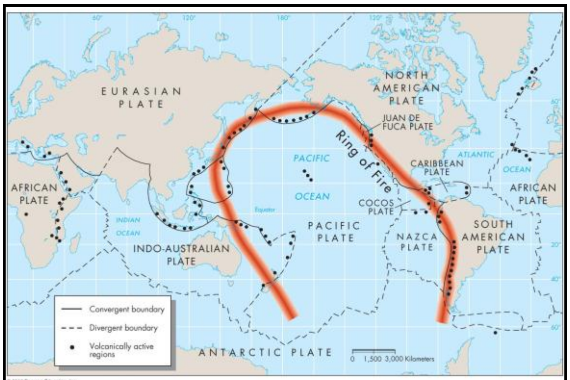
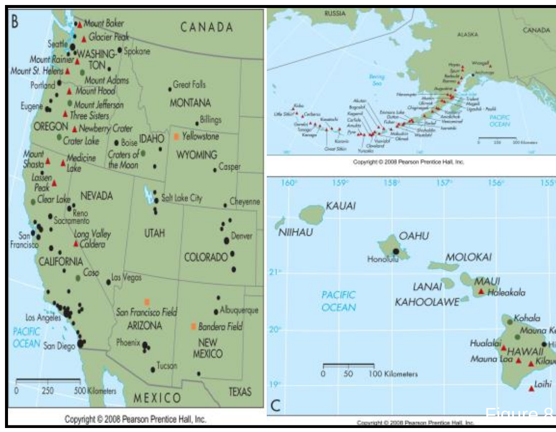


Figure 8.4



How Magma Forms

- Most magmas come from the asthenosphere
- Temperature: Increases with depth close to the temperature at which rocks melt, two additional factors:
- **Decompression melting**: Occurs when the overlying pressure exerted on hot rock within the asthenosphere is decreased
- **Addition of volatiles**: Lowers the melting temperature of rocks

Molten Material

Volcanism is derived from partially melted Earth materials:

- Magma below Earth's surface
- Lava (plus ash, etc.) above Earth's surface

- Magma and lava is generally composed of:
  - Melt – liquid parts
  - Solids – crystallized minerals
  - Volatiles – dissolved gases (H_2O, CO_2, SO_2)

Volcano Types

- Shield, composite (stratovolcano), cinder cone
- Volcanic eruption style
  - Depending on lava's viscosity and amount of dissolved gas (volatiles) content
  - *Viscosity*: Liquid's resistance to flow
    - Determined by silica content (lava composition) and lava temperature
  - Quiet flow (low viscous basalt flow) to violent explosion (high viscous lava eruption)

Shield Volcanoes

- The largest volcanoes
- Common in Hawaii, Iceland, Indian Ocean islands
- Shaped like a shield
- Lava tends to flow down sides of volcano rather than exploding violently, because of low viscosity
- Common rock type is basalt…some tephra (ash)
- Lava tubes often move magma underground for many kilometers
- Typically have summit caldera

Shield Volcano – Mauna Loa

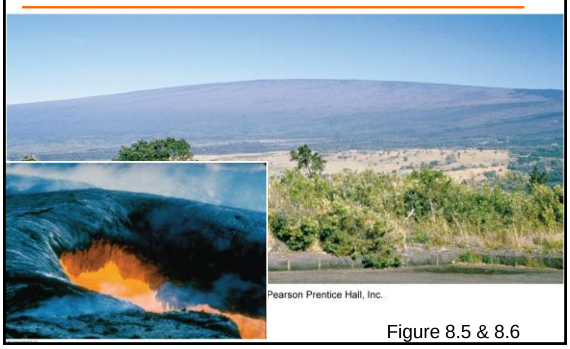


Figure 8.5 & 8.6

Composite or Stratovolcano

- Known for beautiful cone shape
- United States examples include Mt. St. Helens, Mt. Rainier
- Magma with intermediate composition, moderate viscosity
- Erupt with mixture of pyroclastic activity and lava flows, producing layers of pyroclastic deposits and lava flows
- Most deadly and destructive volcanic hazards

Volcanic domes

- Usually fills craters of composite volcanoes
- Viscous magma (rhyolite) with relatively high silica content
- Activity is mostly explosive

Composite Volcano – Mt. Rainier

Cinder Cone - Paricutin

- Relatively small
- Formed from tephra accumulated near volcanic vent
- Often found along flanks of:
  - Larger shield volcanoes
  - Normal faults
  - Cracks or fissures

Figure 7.

TABLE 8.2 Types of Volcanoes

Volcano Type	Shape	Silica Content of Magma	Viscosity	Rock Type Formed	Eruption Type	Example
Shield volcano	Gentle arch, or shield shape, with shallow slopes; built up of many lava flows	Low	Low	Basalt	Lava flows, tephra ejections	Mauna Loa, Hawaii Figure 8.5
Composite volcano, or stratovolcano	Cone-shaped; steep sides; built up of alternating layers of lava flows and pyroclastic deposits	Intermediate	Intermediate	Andesite	Combination of lava flows and explosive activity	Mt. Fuji, Japan Figure 8.7
Volcanic dome	Dome shaped	High	High	Rhyolite	Highly explosive	Mt. Lassen, CA Figure 8.8
Cinder cone	Cone shaped; steep sides; often with summit crater	Low	Low	Basalt	Tephra (mostly ash) ejection	Springerville, AZ Figure 8.9

Table 8.2

Volcanic Origin

- Mid-ocean ridge volcanism produces basalt
  - Wells up directly from asthenosphere
- Shield volcanoes form above hot spots
  - Example: Hawaiian Islands
- Composite volcanoes
  - Andesitic rocks
  - Subduction zones: rising magma mixes with oceanic and or continental crust
  - Most common volcanoes on Pacific Rim
- Caldera-forming eruptions
  - Extremely violent and explosive
  - typically rhyolitic magma produced when magma moves upward and mixes with continental crust

Volcanic Origin and Plate Boundary

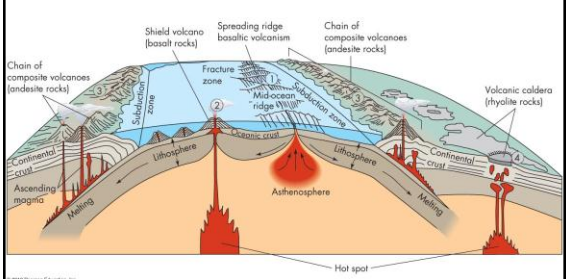


Figure 8.11

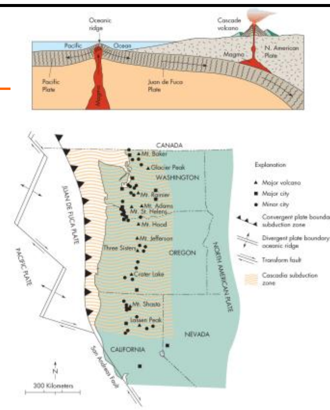


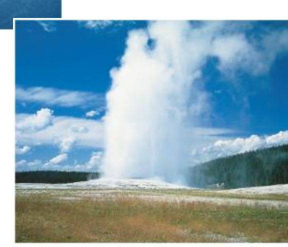
Figure 8.13

Volcanic Features

- Craters (opening <1km diameter) and vents
- Volcanic domes
- Calderas (opening >1km diameter) – collapsed crater typically from explosive eruptions
- Hot springs and geysers
- Fissure line – basaltic lava flows from crack in crust

Columbia River Basalts

Old Faithful Yellowstone



(a)

Figure 8.14 and 8.15a

Yellowstone – Grand Prismatic Spring

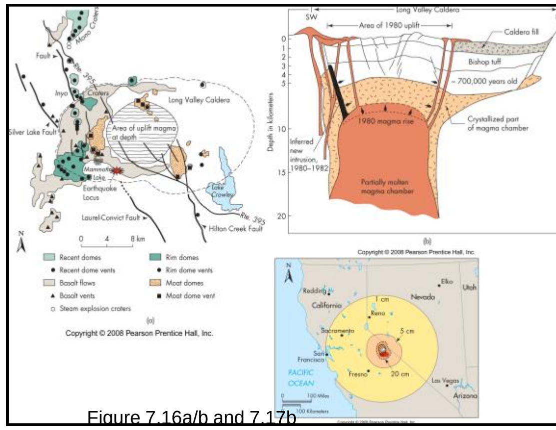


Figure 7.16a/b and 7.17b

Volcanic Hazards & Impact Risks

Both 'direct' and 'indirect' effects:

Lava Flows

Pyroclastic activity

Poisonous gases

Debris flows and mudflows (lahars)

(a)

Figure 8.20a

Volcanic Hazards & Impact Risks

Lava flows: from the vent or a crater or along a line of fissure

- Most common and abundant type: basaltic
  - Pahoehoe lava – less viscous, higher temperature, with a smooth ropy surface texture
  - Aa lava – more viscous and slow moving, lover temperature, with a

Figure 8.19

Volcanic Hazards & Impact Risks

Basaltic Lava Flows

Figure 8.18a/b

Volcanic Impact Risks

Pyroclastic flow

- Large amount of rock fragments, volcanic glass fragments, and volcanic bombs
- Associated with explosive volcanic eruptions
- Ash fall, from a more vertical ash eruption
- More deadly if lateral blast
- Pyroclastic hot avalanches, nueé ardentes, French for "glowing cloud"
- Hot temperature and fire hazards

During the May 18, 1980

- 17 separate pyroclastic flows descended the flanks of Mount St. Helens.
- Pyroclastic flows can move at speeds of over 60 mph
- Temperatures up to 800 Degrees Fahrenheit

Photographed here, a pyroclastic flow from the August 7, 1980 eruption stretches from Mount St. Helens' crater to the valley floor below. USGS Photograph taken on August 7, 1980, by Peter W. Lipman.

Volcanic Impact Risks

- More on ***ash*** fall and ash flow
  - Covering large area, 100s or 1,000s of km^2
  - Wider impact if ash flows reach upper atmosphere
  - Hot temp (nueé ardentes) ash and moving at rapid speed (100 km/h)
  - Harm to human health and structures
  - Blocking away solar radiation
  - Hazardous for air traffic

Volcanic Impact Risks (4)

Poisonous Gases:

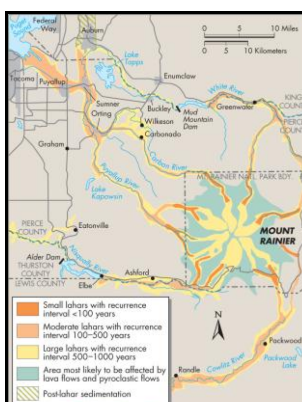
- Volcanic gases – H_2O, CO_2, CO, SO_2, H_2S
- Floating in air
- Dissolved in water
- Danger to health, plants, and animals
- Produces smog air (vog), acid rain (lead contamination from construction materials), and toxic soils
- Health effects of vog – breathing problems, headaches, sore throats, watery eyes

(b) (c)

Volcanic Impact Risks (5)

Debris Flows and Mudflows:

- Most serious secondary volcanic hazards
- Collectively called "**lahar**"
- From the collapse of volcano sides
- From sudden melting of snow and glaciers
- Far-reaching distance – tens of miles from volcano
- Rapid downslope flow rates of ~25 mph
- Can trigger submarine avalanche and tsunami



5,000 year-old Osceola mudflow flowed N

- 50 mi from source
- Debris equivalent to 5-mi^2 at depth of 492'

500 year-old Electron mudflow flowed NW

- 35 mi from source

Figure 8.24

Case Study – Mt. Pinatubo

Philipines

- June 15–16, 1991
- Killed 350 people and destroyed a U.S. military base
- Nearly 1-ft depth of ash covered buildings over a 40-km radius
- Huge cloud of ash 400 km wide into nearly 40-km elevation
- Affected global climate (cooler summer the next year; global temp differences −0.5°C, ~1°F)

Evacuation of 250,000 people within a radius of 19-mi saved thousands of lives.

Figure 8.26

Case Study – Mount St. Helens

Washington, USA

- May 18, 1980 eruption after 120 years
- Earthquake (M 5.1) precursor
  - Triggered massive landslide
  - Displaced water in Spirit Lake
  - Traveled ~11-mi down Toutle River
- Lateral blast moved at 621 mph and impacted area 19-mi from the source
- Mudflows reached nearly 60 miles away to Cowlitz and Columbia Rivers

Case Study – Mount St. Helens

- Eruption of material for over 9 hours
- Ash column over 12-mi in elevation
- Ash (tephra) materials spread over WA, ID, and west MT
- Volcanic peak reduced by over 1,476 feet
- Killed 54 people, damaged 100 homes and 800 million feet of timber
  - Total cost $3 billion

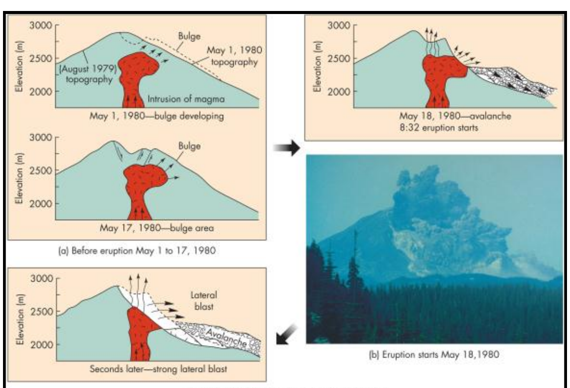
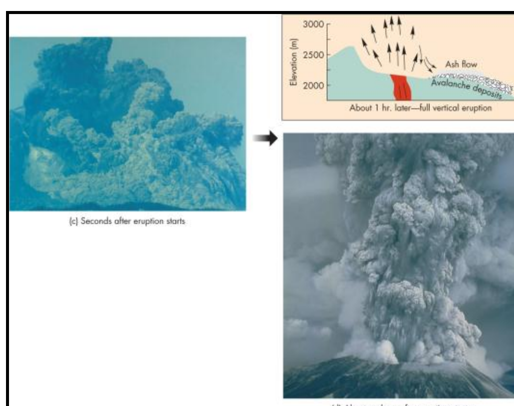


Figure 8.28



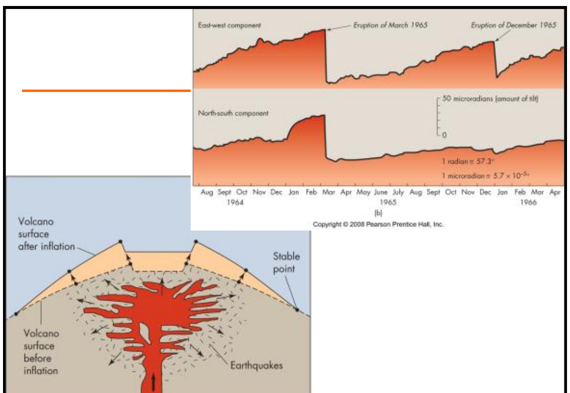

(b)

Figure 8.27 b/c


(a)

Forecasting Volcanic Activity

- Seismic activities: earthquakes as precursors
- Thermal, magnetic, and hydrologic conditions
- Amount of volcanic gas emission, both rate and composition
- Topographic monitoring: tilting and bulging
- Remote sensing: radar 3-D interferometry
- Geologic history of the volcano



(b)
(a)

Figure 8.33 a/b

Volcanic Alert or Warning

TABLE 8.3 Volcanic Activity Color Coded Alert Notification System.

GREEN Normal	Volcano is in typical background, non-eruptive state or, *after a change from a higher level,* volcanic activity has ceased and volcano has returned to noneruptive background state.
YELLOW Advisory	Volcano is exhibiting signs of elevated unrest above known background level or, *after a change from a higher level,* volcanic activity has decreased significantly but continues to be closely monitored for possible renewed increase.
ORANGE Watch	Volcano is exhibiting heightened or escalating unrest with increased potential of eruption, timeframe uncertain, **OR** eruption is underway with no or minor volcanic-ash emissions (ash-plume height specific, if possible).
RED Warning	Eruption is imminent with significant emmission of volcanic ash into the atmosphere likely **OR** eruption is underway or suspected with significant emission of volcanic ash into the atmosphere (ash-plume height specified, if possible).

Modified from U.S. Geological Survey 2007. http://volcanoes.usgs.gov.

http://volcanoes.usgs.gov/

Table 8.3

Public Perception and Adjustment

Perception of the volcanic hazards

- Age and residence time affecting one's perception
- No other choices as where to live
- Optimistic and accepting risks

Adjustment

- Public awareness and education
- Improvement in education
- Better scientific info dissemination
- Timely and orderly evacuation

Applied and Critical-Thinking Topics

- What are the possible reasons why people live near a volcano?
- Is your area vulnerable to the impact risks of volcanic activities?
- How do political and economic factors influence people's attitude toward the volcanic hazard?
- How to develop a public relations program that could alert people to a potential volcanic hazard?