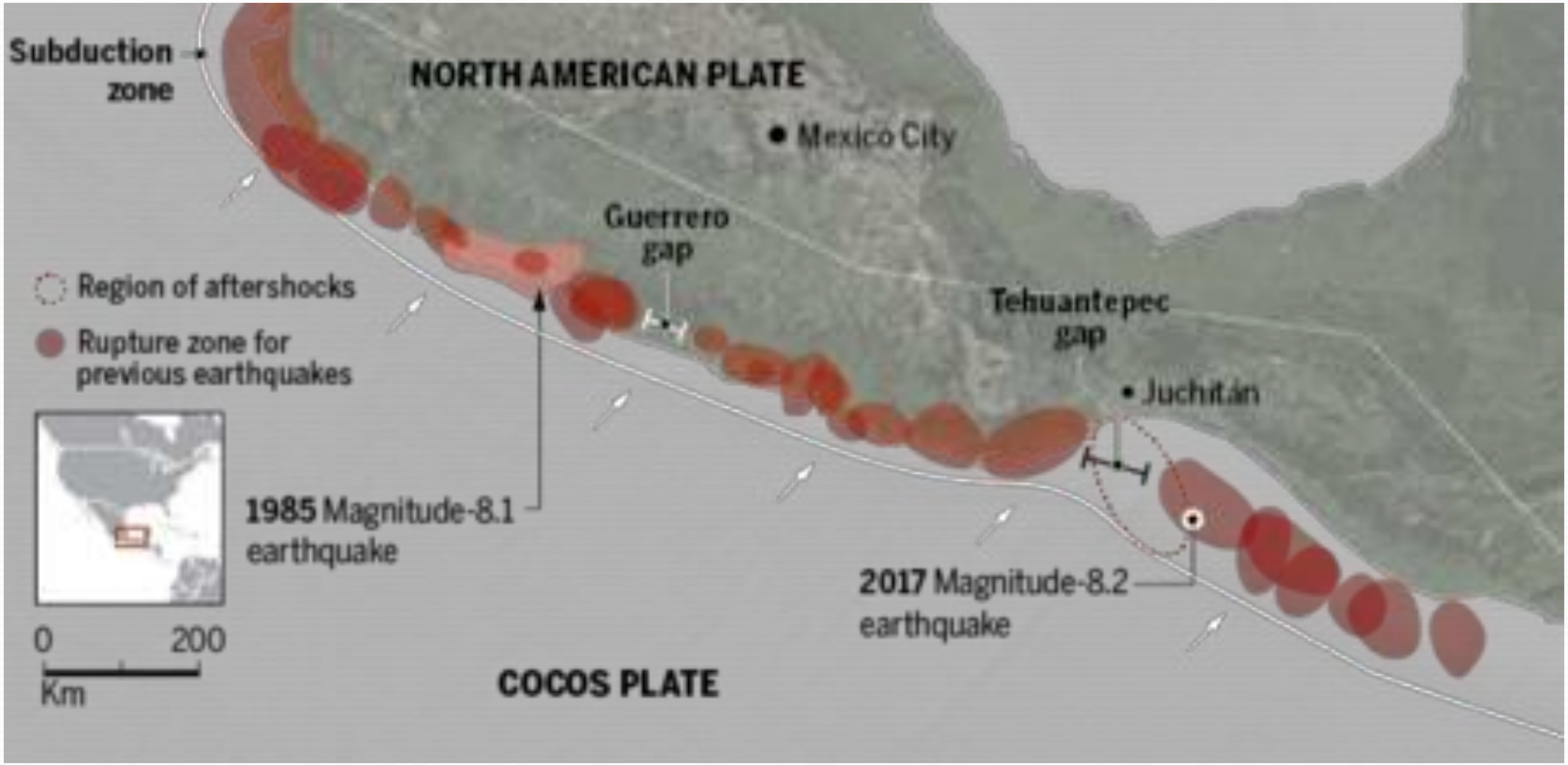
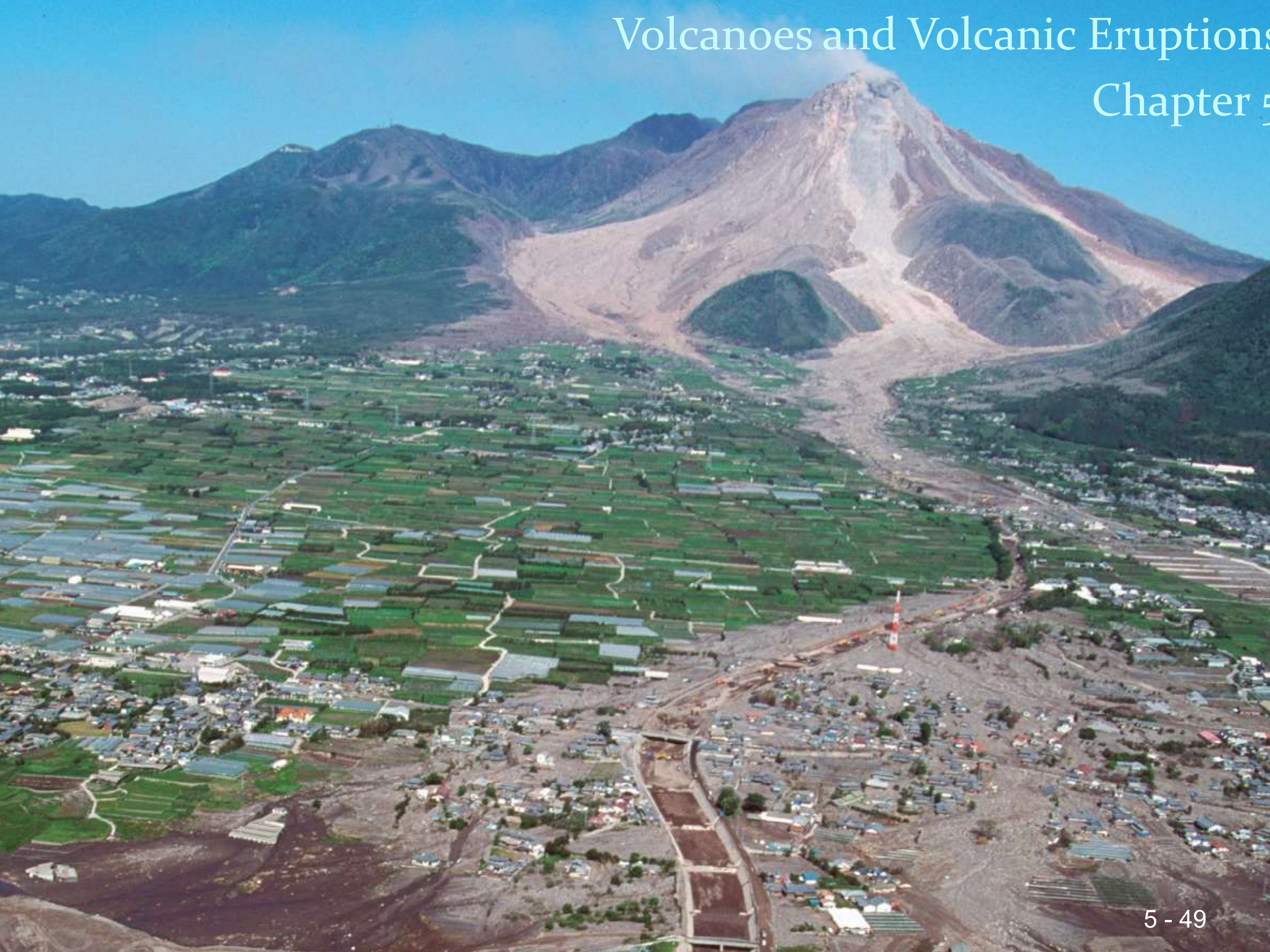

Subduction zone
NORTH AMERICAN PLATE
Mexico City
Guerrero gap
Region of aftershocks
Rupture zone for previous earthquakes
Tehuantepec gap
Juchitán
1985 Magnitude-8.1 earthquake
2017 Magnitude-8.2 earthquake
0
200
Km
COCOS PLATE



Learning Objectives

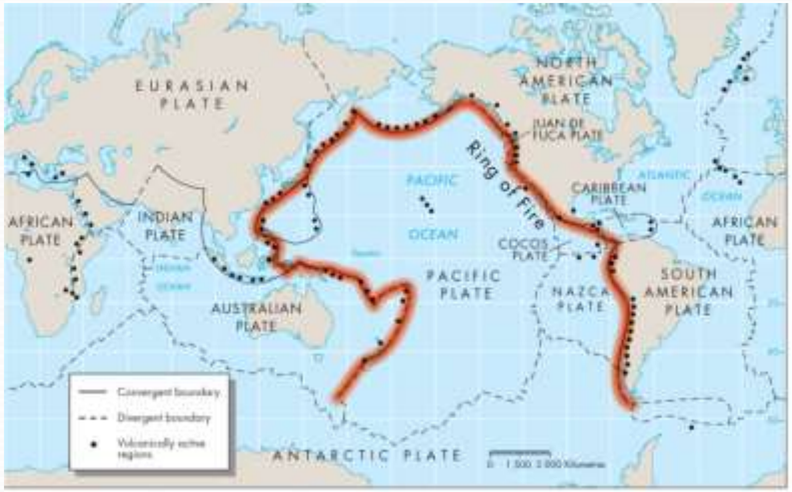
1. Know the different types of volcanoes
2. Understand the relation between volcanoes and plate tectonics, and know where volcanoes occur on Earth
3. Understand the effects of volcanic eruptions
4. Know how volcanoes are linked to other natural hazards

Learning Objectives

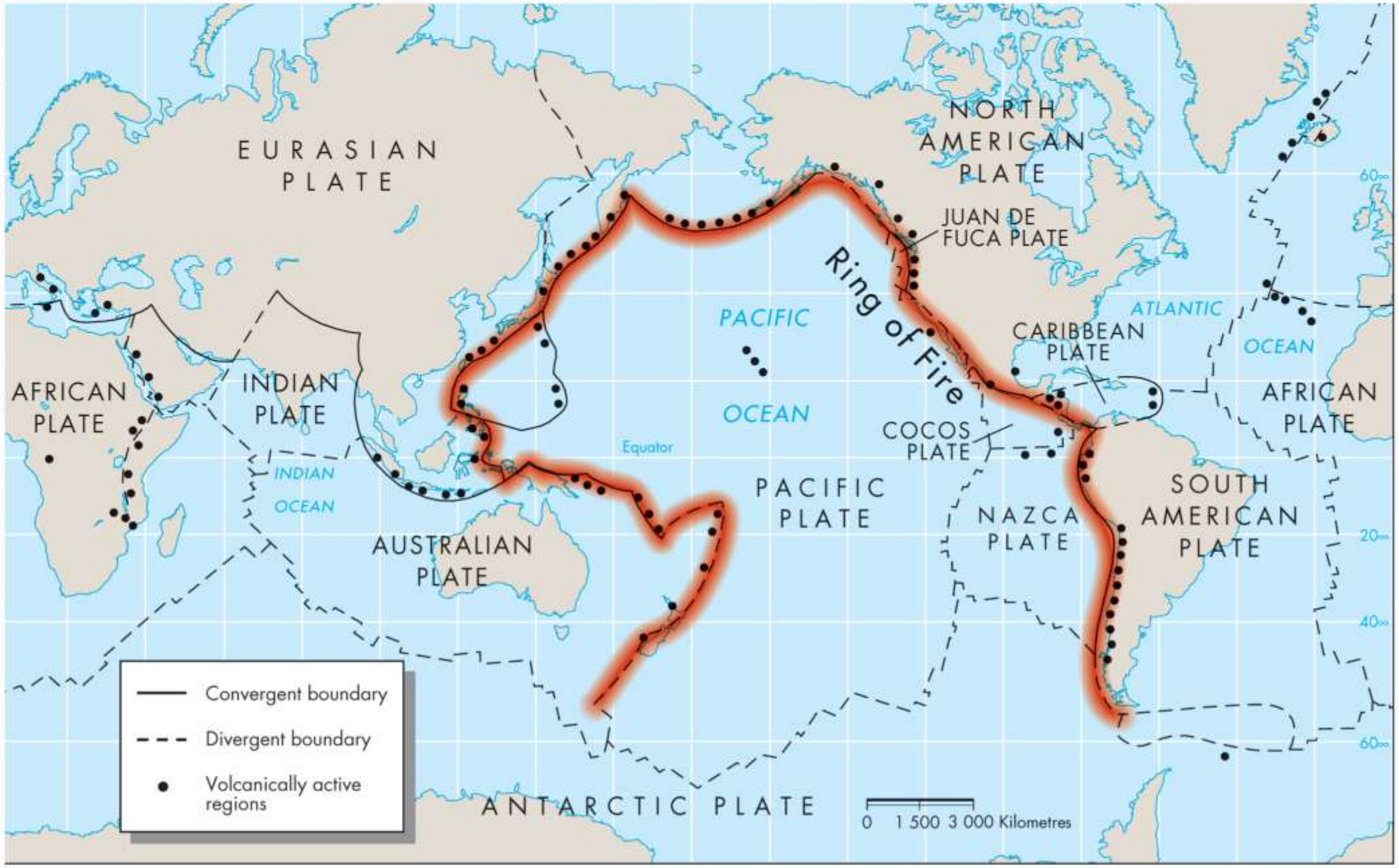
5. Recognize the benefits of volcanic eruptions
6. Know the premonitory signs of volcanic eruptions
7. Know the adjustments that people can make to avoid death and reduce damage from volcanic eruptions

Introduction

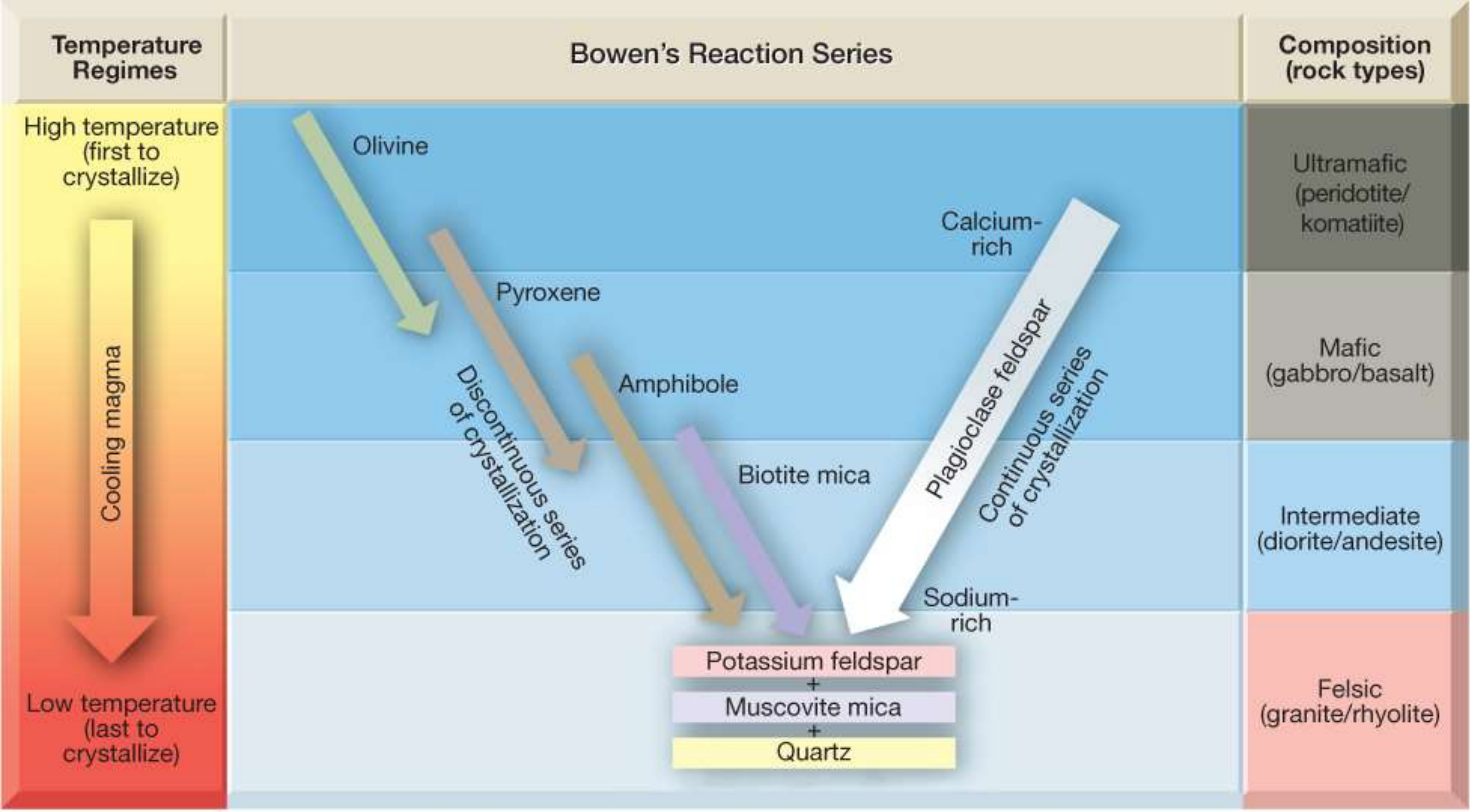
- Most active volcanoes are located near plate boundaries
- Mid-ocean ridges and subduction zones are sites where molten rock reaches the surface
  - Magma is molten rock
  - Lava is magma on the Earth's surface
- 2/3 of all active volcanoes on land are located along the **Ring Of Fire** which surrounds the Pacific Ocean



▲ FIGURE 5.3 THE RING OF FIRE The orange band in this drawing is the Ring of Fire, a belt of active volcanoes and frequent earthquakes bordering the Pacific plate. The Ring of Fire includes most of the world's onshore active volcanoes. *(Modified from Costa, J. E., and V. R. Baker. 1981. Surficial Geology. Fairfax, VA: Techbooks. Reprinted with permission of John Wiley & Sons.)*



▲ **FIGURE 5.3 THE RING OF FIRE** The orange band in this drawing is the Ring of Fire, a belt of active volcanoes and frequent earthquakes bordering the Pacific plate. The Ring of Fire includes most of the world's onshore active volcanoes. *(Modified from Costa, J. E., and V. R. Baker. 1981.* Surficial Geology. *Fairfax, VA: Techbooks. Reprinted with permission of John Wiley & Sons.)*



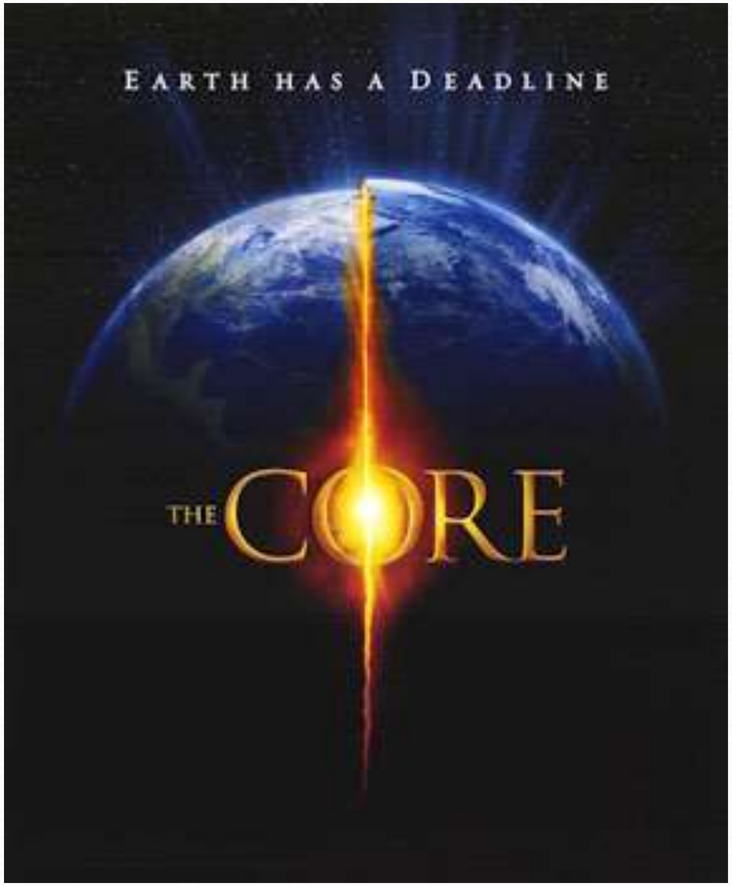
▲ **FIGURE 5.8 FRACTIONATION** Sequence of crystallization of minerals in magma as temperature decreases. Olivine, pyroxene, and calcium-rich plagioclase crystallize at the highest temperatures. Quartz, potassium feldspar, and muscovite crystallize later, at lower temperatures. *(Tarbuck, E. J., F. Lutgens, and D. Tasa. 2008.* An Introduction to Physical Geology, *9th ed. Pearson Education Inc., Upper Saddle River, NJ. Reprinted and Electronically reproduced by permission of Pearson Education, Inc., Upper Saddle River, New Jersey.)*

Don't have to know this shit

Why is it important to understand how volcanoes work?

- To understand/predict volcanic hazards

	# killed
Laki (1783), Iceland	>10,000
Mt Pelee (1902), Martinique	>30,000
Mt St. Helens (1980)	57
Nevado del Ruis (1985), Columbia	>20,000
Montserrat (1995), Martinique	19



To understand nature of Earth's interior

Resource exploration

- New Zealand, Iceland, Canada (B.C)

Terminology

- **Magma** - molten rock

- **Lava** - magma that reaches the earth's surface

- **Pyroclastic debris** - lava and rock fragments ejected in a volcanic eruption

Volcanic bomb

lapilli

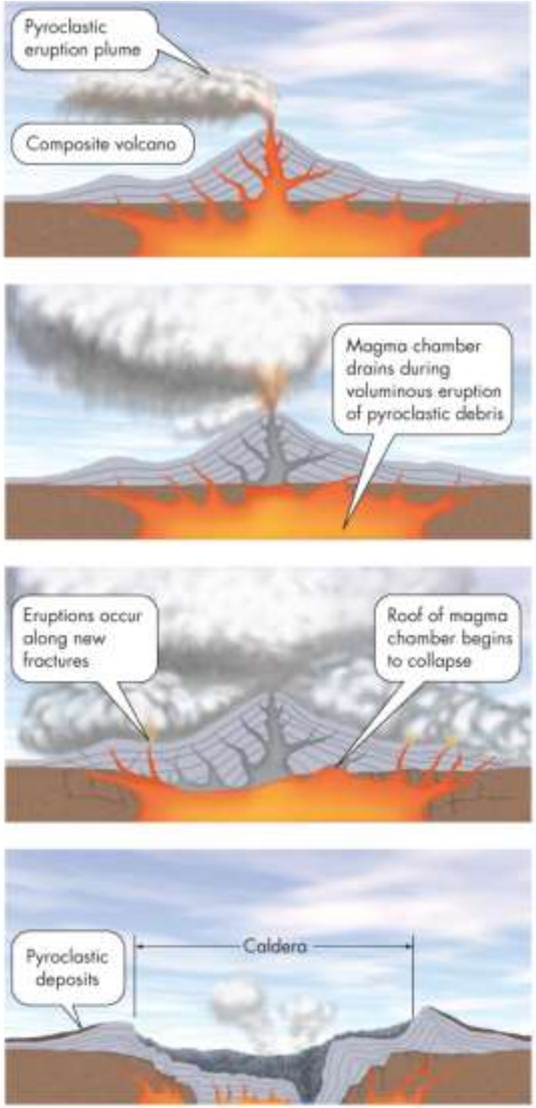
Ancient volcanic ash layers

- **Volcano** - hill or mountain produced by volcanism

- **Vent** - opening through which eruption takes place

- **Crater** - depression over the vent

- **Caldera** - depression > 1km wide

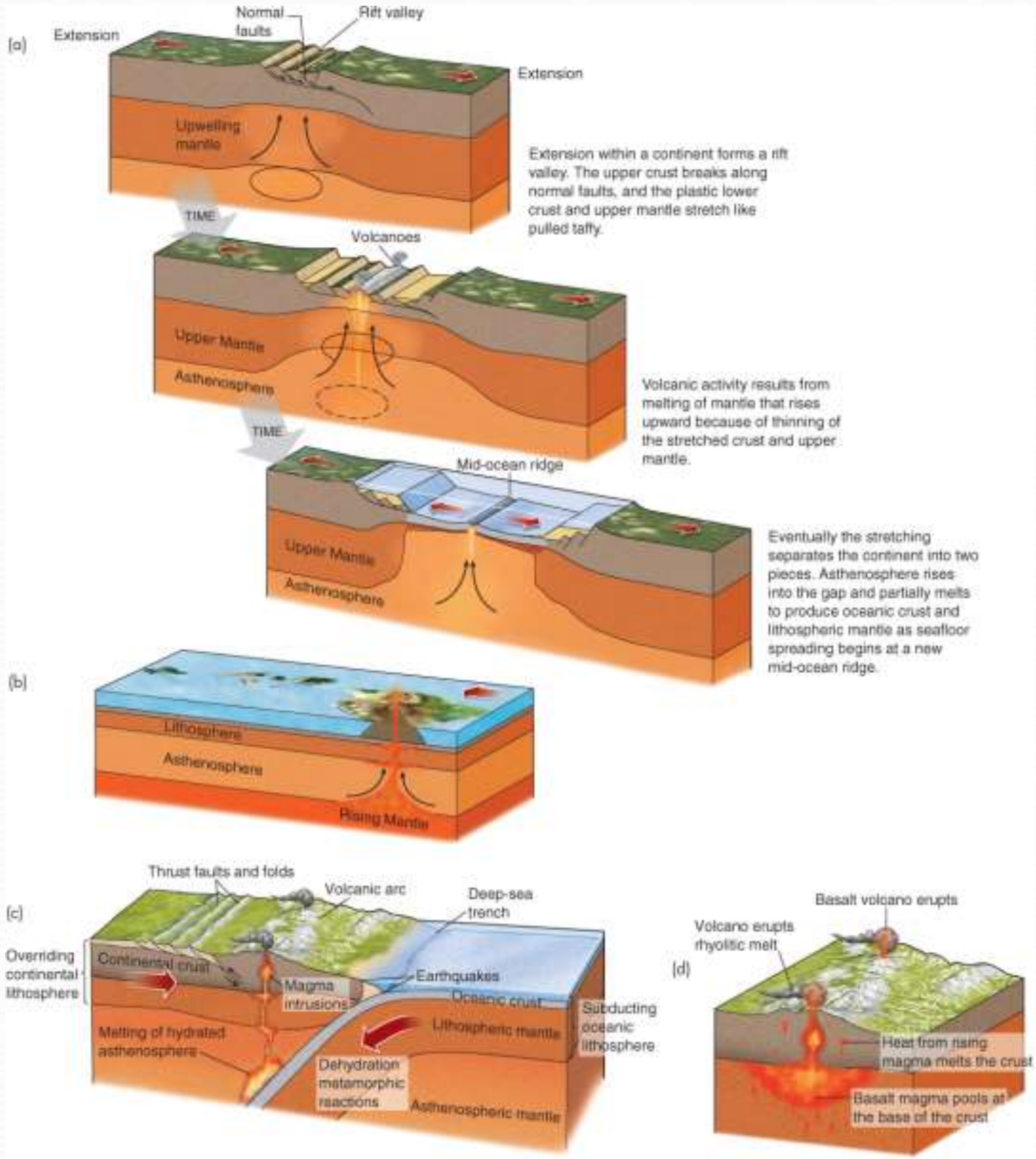


▲ **FIGURE 5.20 CALDERAS FORM BY EXPLOSION AND COLLAPSE** Calderas generally form by collapse of a magma chamber below a composite volcano during and shortly after an explosive eruption. The largest calderas on Earth, located in Yellowstone National Park (Wyoming), California, and New Zealand, are tens of kilometres across. *(Modified from Smith, G. A., and A. Pun 2006.* How Does Earth Work? Physical Geology and the Process of Science. *Upper Saddle River, NJ: Pearson Prentice Hall. Reprinted and Electronically reproduced by permission of Pearson Education, Inc., Upper Saddle River, New Jersey.)*

How Magma Forms

- Most magmas come from the asthenosphere
  - Weak, but not liquid, layer of rock

- Three main ways in which silicate rocks can melt:
  - Decompression
    - Pressure exerted on hot rock is reduced
    - Occurs at divergent boundaries, continental rifts, and hot spots
  - Addition of volatiles
    - Chemical compounds that lower the melting temperature of the rock
  - Addition of heat
    - As magmas rise, they release heat to overlying rocks



▲ **FIGURE 5.4 MAGMA FORMATION** Magma is generated primarily within the asthenosphere. (a) Decompression melting occurs when the overburden pressure on rocks in the asthenosphere is lowered due to thinning of the overlying lithospheric plate. (b) Decompression melting also occurs when super-heated rocks well up from deep within the asthenosphere at a hot spot. (c) Addition of volatiles to the asthenosphere from a down-going oceanic plate causes melting at a subduction zone. (d) Heat within rising magma causes the adjacent lithosphere to melt.

Magma Properties

- Magma is composed of melted silicate minerals and dissolved gases

- Two most abundant elements in magma are silicon (Si) and oxygen (O); when combined, they are referred to as silica (SiO_2)

- Volcanic rocks are named depending on the amount of silica present in the rock
  - basalt, andesite, dacite, rhyolite

- Affect style of eruption and type of volcano produced
    - Silica content of magma is critical

- Silica-rich (felsic) lavas
    - – very viscous, flow slowly
    - – gases cannot escape easily
    - – violent eruptions, explosive
    - – e.g. ***rhyolite***

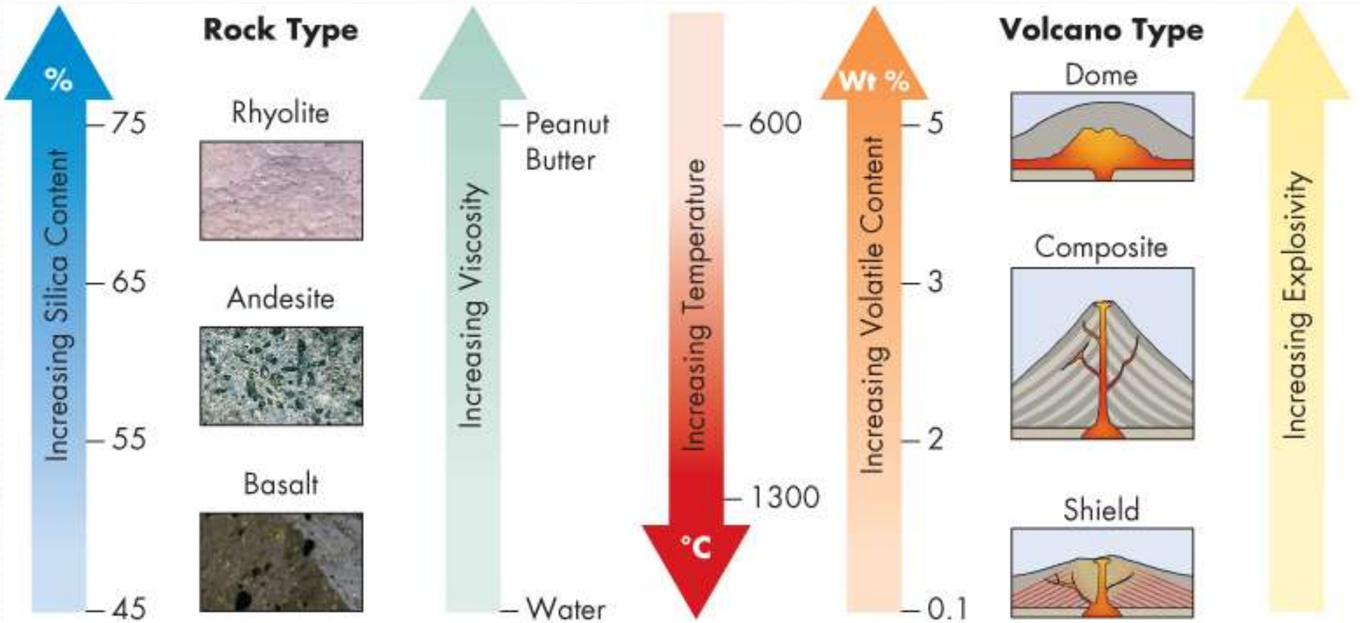
- Silica-poor (mafic) lavas
  - low viscosity, flow eas
  - gases escape easily
  - quiet eruptions, lava flows
  - e.g. ***basalt*** most common

- Intermediate lavas - e.g. ***andesite***

Magma Properties

- Silica content affects viscosity
  - Silica-rich magma does not flow easily and has a high viscosity
  - Viscosity affects the flow of lava and therefore the shape of the resulting volcano

- Volatile content determines how explosive the eruption will be
  - High concentration of dissolved volatiles will explode violently
  - Volatile content increases with increasing silica content
- In explosive eruptions, **tephra** is ejected
  - Small fragments of pyroclastic debris
  - An accumulation of tephra is a **pyroclastic deposit**



◄ **FIGURE 5.5 VOLCANO CHARACTERISTICS** The silica content and viscosity of magma are related. The silica content of the magma also defines the resulting volcanic rock type, as well as the shape and type of the associated volcano. High-silica magmas generally have higher volatile contents than low-silica magmas, and they generate explosive eruptions when they reach the surface.

Types of Volcanoes

- Different shapes and eruptive styles are based on the chemistry and viscosity of magmas

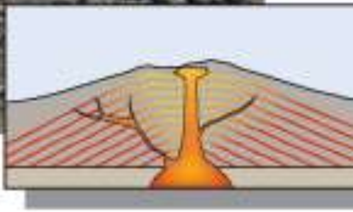
TABLE 5.1 Types of Volcanoes

Volcano Type	Shape	Silica Content of Magma	Viscosity	Rock Type	Eruption Type	Example
Shield volcano	Gentle arch or dome with gentle slopes	Low	Low	Basalt	Lava flows, some explosive activity	Mauna Loa, Hawaii, Figure 5.6
Composite volcano or stratovolcano	Cone-shaped with steep sides	Intermediate	Intermediate	Andesite	Combination of lava flows and explosive activity	Volcan Osorno, Chile, Figure 5.10
Volcanic dome	Dome shaped	High	High	Rhyolite	Highly explosive	Mono Craters, California, Figure 5.15
Cinder cone	Steep cone, commonly with summit crater	Low	Low	Basalt	Explosive activity	Mount Edziza, British Columbia, Figure 5.16

Shield Volcanoes

- Largest volcanoes in the world
  - Gentle slopes built almost entirely of lava flows
  - Resembles a warrior's shield by area
  - Common in Hawaiian Islands, Iceland, and Indian Ocean
- Associated with basaltic magma
  - Low viscosity, low gas content, no **fractionation**
- Gentle flowing lava with non-explosive eruptions
- Can form lava tubes underground

FIGURE 5.6 SHIELD V
Mauna Loa, a classic sh
cano formed from countle
tions of basalt. Note that t
of the volcano is very gent
like that of a warrior's sh
volcano's diameter is m
80 km. (Duane DeVecchio)



Composite Volcanoes

- Explosions are more violent but less frequent
  - Produce a combination of lava flows and pyroclastic deposits
- Conical in shape, also called stratovolcanoes
  - Many active volcanoes on west coast of North America
- Eruptions involve andesitic or dacitic magmas
  - High silica and low viscosity

◄ FIGURE 5.10 STRATOVOLCANO Volcan Osorno in Chile is a beautiful, snow-clad composite volcano that last erupted in 1869. © Paul Street/Alamy

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ful,
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Volcanic Domes

- Form around vents from the eruption of highly viscous silica-rich magma
- Exhibit explosive eruptions
- Small domes often form within the crater after an eruption

◄ FIGURE 5.15 VOLCANIC DOME Mono Craters in California are volcanic domes consisting of rhyolitic and dacitic lavas. The volcanoes range in age from about 600 to 40 000 years old. *(Long Valley Observatory, U.S. Geological Survey)*

Cinder Cone Volcanoes

◄ FIGURE 5.18 CINDER CONE Eve Cone, which is part of the Mount Edziza shield volcano in northwest British Columbia, has a small crater at its summit. (Natural Resources Canada 2010, courtesy of the Geological Survey of Canada/C. J. Hickson)

- Small volcanoes
- Built from small pieces of red or black basalt
- Found on the flanks of larger volcanoes, along some normal faults, and along cracks or fissures
- Tephra from extinct cinder cones is the “lava rock” used widely in commercial landscaping

◄ FIG
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Maars and Ice Contact Volcanoes

- The violent interaction of magma and groundwater produces **maars**
  - Roughly circular volcanic craters commonly filled with water

- Ice Contact Volcanoes
  - Erupt beneath or against glaciers
  - Subglacial volcanoes erupt, rapidly melting ice and produce huge floods known as jokulhlaups
  - Ex: Iceland, Mt. Garibaldi

Volcanic Features,

- **Hot springs**
  - Hot rocks heat groundwater that discharges at the surface

- **Geysers**
  - Groundwater boils in an underground chamber, erupting steam at the surface

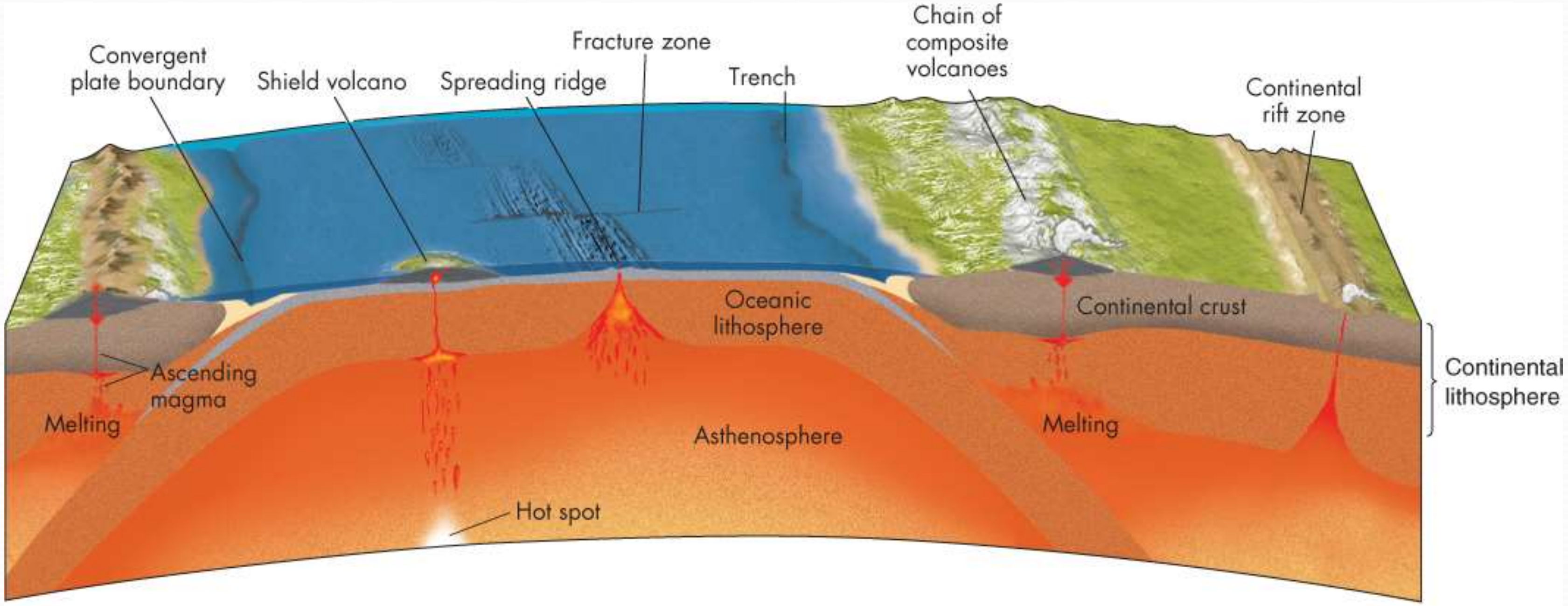
◄ FIGURE 5.21 OLD FAITHFUL An eruption of Old Faithful Geyser in Yellowstone National Park, Wyoming. Although the geyser's name implies predictability, eruption intervals vary from day to day and year to year and often change after earthquakes. *(John J. Clague)*

Volcanic Features,

- Resurgent Calderas and Super Eruptions
  - Very rare but extremely violent eruptions from **supervolcanoes**
  - Produce huge amounts of ash and form calderas
  - Most recent North American caldera eruptions were [Yellowstone National Park]

▲ FIGURE 5.22 **WIDESPREAD ASH FALL HAZARD** The area in orange was covered by ash from the Long Valley caldera eruption approximately 700 000 years ago. The red circle around Long Valley (LV) has a radius of 120 km and encloses the area that would receive more than 1 m of ash if a similar eruption were to occur again. *(From Miller, C. D., D. R. Mullineaux, D. R. Crandell, and R. A. Bailey. 1982.* Potential Hazards from Future Volcanic Eruptions in the Long Valley–Mono Lake Area, East-central California and Southwest Nevada—A Preliminary Assessment. *U.S. Geological Survey Circular 877)*

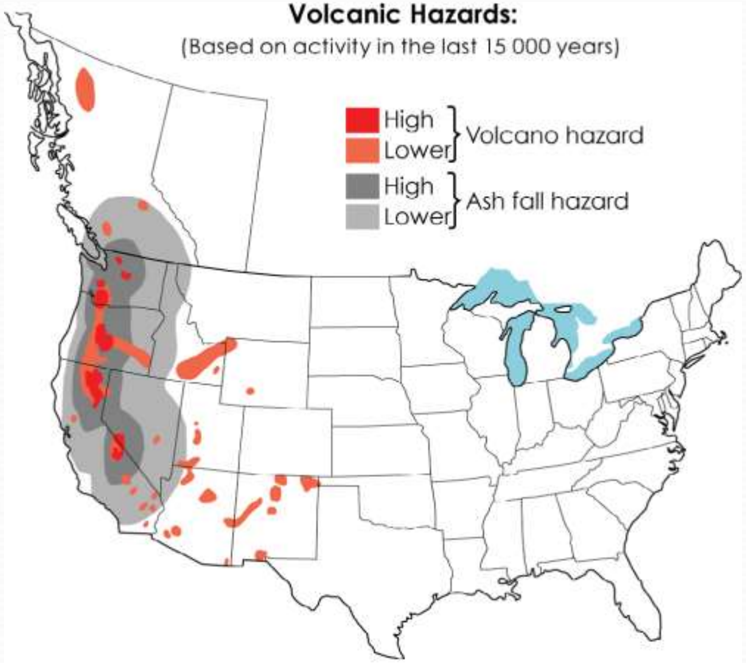
Volcanoes and Plate Tectonics



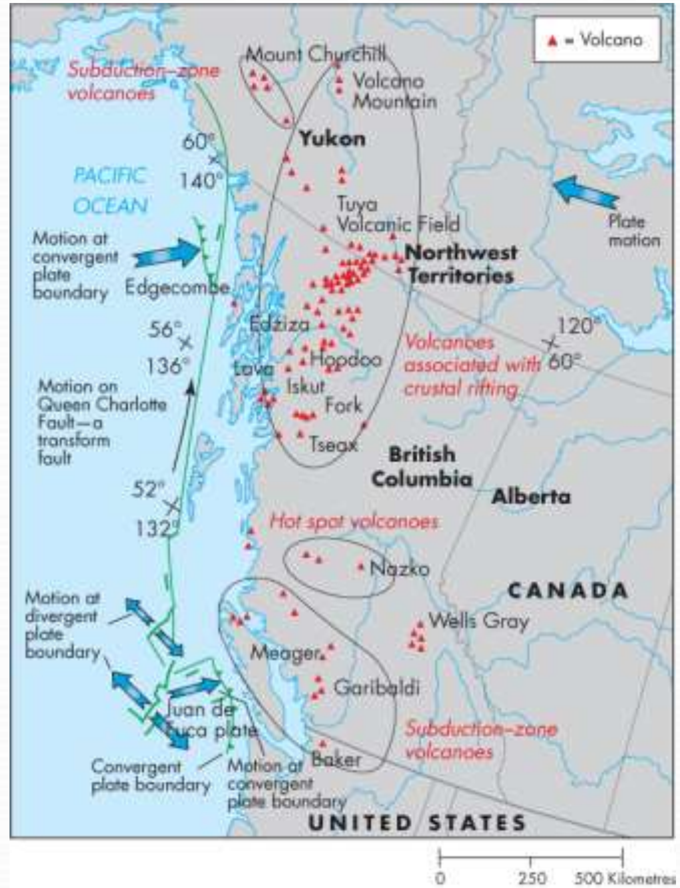
▲ **FIGURE 5.23 VOLCANIC ACTIVITY AND PLATE TECTONICS** An idealized diagram showing plate tectonic processes and their relation to volcanic activity. Numbers refer to explanations in text. *(Modified from Skinner, B. J., and S. C. Porter. 1992.* The Dynamic Earth, *2nd ed. New York: John Wiley)*

Geographic Regions with Active Volcanoes

- Ring of Fire
  - Pacific Ocean subduction zones
  - Highest risk in Canada is in northwestern and central B.C.
- Hot spots
  - Hawaii and Yellowstone National Park
- The volcano that poses the greatest risk to Canada is Mt. Baker in northern Washington State.
  - An eruption could spread ash over Vancouver



▲ **FIGURE 5.26 CANADIAN AND U.S. VOLCANIC HAZARD** Volcanic hazard for Canada and the contiguous United States based on activity during the past 15 000 years. The red colours show high and lower local volcanic hazard. The grey area is at risk of receiving 5 cm or more of ash fall from large explosive eruptions. *(Adapted from U.S. Geological Survey)*



▲ **FIGURE 5.27 VOLCANOES AND THEIR TECTONIC ENVIRONMENTS IN WESTERN CANADA** Recent volcanic activity in western Canada occurs in three tectonic settings: (1) along convergent plate boundaries, where one plate subducts beneath another (for example, Mount Garibaldi and Mount Meager); (2) in regions where the North American plate is rifting (for example, Mount Edziza and the Iskut River area); and (3) at hot spots where upwelling magma breaks through the crust (Nazko). The green lines delineate transform faults. Zones of different types of volcanism are circled. *(Reproduced or adapted with the permission of Natural Resources Canada 2013, courtesy of the Geological Survey of Canada (Bulletin 548))*

Effects of Volcanoes

- 50 to 60 volcanoes erupt each year
  - Most eruptions are in sparsely populated areas
- Nearly 100,000 people have been killed by eruptions in the past 100 years
- 500 million people live in the vicinity of volcanoes
  - Japan, Mexico, Philippines, Indonesia
  - Western North America

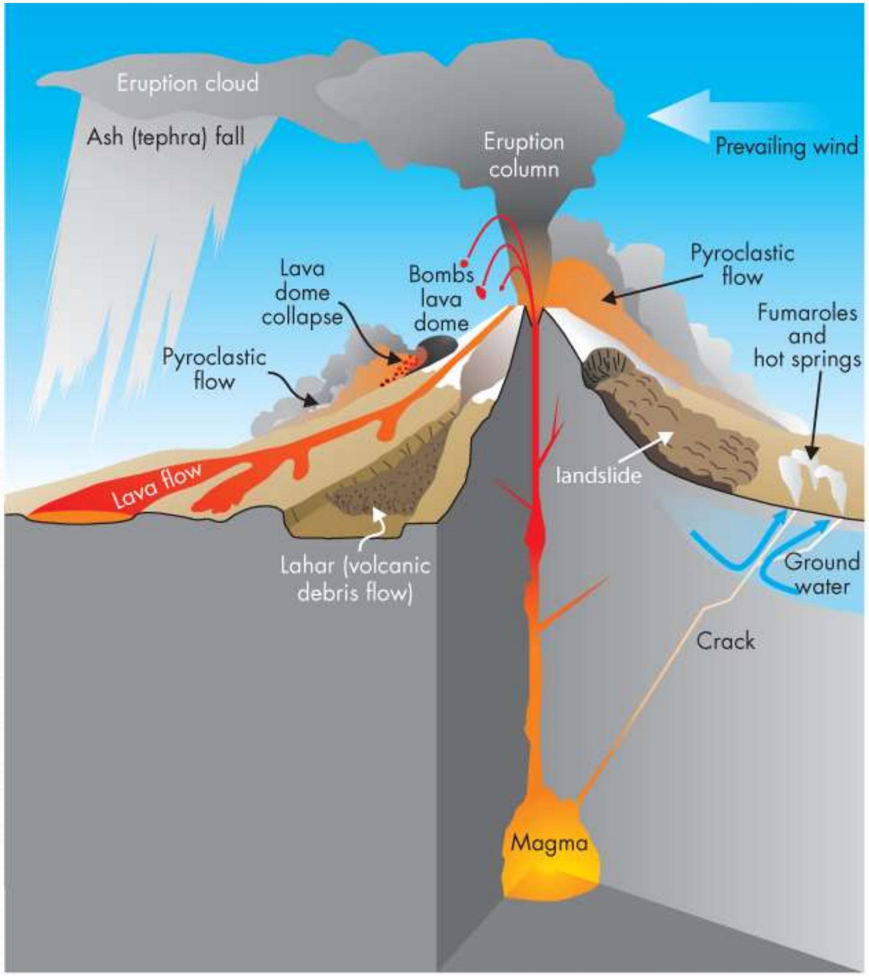
TABLE 5.2 Selected Historic Volcanic Eruptions

Volcano or City	Year	Effect
Vesuvius, Italy	A.D. 79	Destroyed Pompeii and killed 16 000 people; city was buried by volcanic ash and rediscovered in 1595
Skaptar Jökull, Iceland	1783	Killed 10 000 people (many died from famine) and most of the island's livestock; also killed crops as far away as Scotland
Tambora, Indonesia	1815	Global cooling; produced "year without a summer"
Krakatoa, Indonesia	1883	Tremendous explosion; 36 000 deaths from tsunamis
Mount Pelée, Martinique	1902	Pyroclastic flow killed 30 000 people in a matter of minutes
La Soufrière, St. Vincent	1902	Killed 2000 people
Mount Lamington, Papua New Guinea	1951	Killed 6000 people
Villarica, Chile	1963–1964	Forced 30 000 people from their homes
Mount Helgafell, Heimaey Island, Iceland	1973	Forced 5200 people to evacuate their homes
Mount St. Helens, Washington	1980	Debris avalanche, lateral blast, and lahars killed 57 people and destroyed more than 100 homes
Nevado del Ruiz, Colombia	1985	Eruption generated lahars that killed at least 23 000 people
Mount Unzen, Japan	1991	Pyroclastic flows and lahars killed 43 people and destroyed hundreds of homes; 12 000 people evacuated
Mount Pinatubo, Philippines	1991	Tremendous explosions, pyroclastic flows, and lahars combined with a typhoon killed more than 300 people; 60 000 people evacuated
Montserrat, Caribbean	1995	Explosive eruptions, pyroclastic flows; south side of island evacuated, including capital city of Plymouth; several hundred homes destroyed
Chaitén, Chile	2008	Explosive eruptions, pyroclastic flows; 5000 people evacuated; aviation in South America disrupted for weeks
Eyjafjallajökull, Iceland	2010	Large eruption of ash; disrupted air travel in the United Kingdom and northern Europe for several weeks.

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

Volcanic Hazards

- **Primary effects**
  - lava flows, ash fall, volcanic bombs, pyroclastic flows, pyroclastic surges, lateral blasts, and poisonous gases
- **Secondary effects**
  - lahars, debris avalanches, landslides, groundwater and surface contamination, floods, fires, and tsunamis
- The size of an eruption can be quantified using a scale called the Volcanic Explosivity Index [VEI]



◄ **FIGURE 5.29 VOLCANIC HAZARDS** Hazards associated with explosive stratovolcanoes such as Mount Meager, Mount St. Helens, and Mount Rainier. *(Reprinted with permission of Tricouni Press)*

Volcanic Hazards,

- **Lava Flows**
  - Occur when magma reaches the surface
  - Can move slowly or rapidly depending on viscosity and temperature
  - High viscosity moves more slowly

- Basaltic lava flows are the most common
  - Pahoehoe
    - Harden with a smooth ropy texture
    - Travel at speeds of up to a few kilometres per hour
  - Aa
    - Harden with a rough, blocky texture
    - More viscous, travels at rates of a few metres per day

▲ FIGURE 5.30 **PAHOEHOE LAVA FLOW** The ropy surface texture of a pahoehoe lava flow engulfing a home at Kalapana, Hawaii, in 1990. This flow and others produced by eruptions of Kilauea volcano destroyed more than 100 structures, including the Kilauea National Park Service Visitors Center. *(© Paul Richards/Bettmann/Corbis)*

▲ FIGURE 5.31 **AA LAVA FLOW** This aa lava flow is moving over an older flow of pahoehoe lava. Aa has a blocky surface texture that develops on cooler, slower-moving basaltic lava than pahoehoe. *(© J. D. Griggs/Corbis)*

Volcanic Hazards,

Pyroclastic Flows and Surges

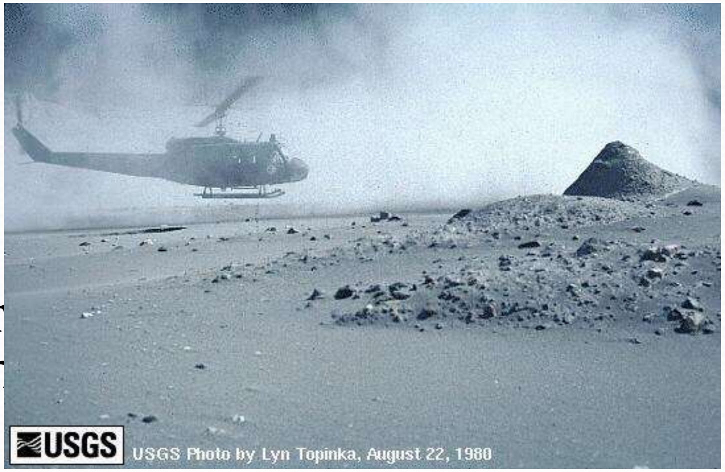
- Flows - avalanches of hot rock, ash, volcanic rock fragments
- Can move at speeds up to 150 km/h
- Surges - dense clouds of hot gas and rock debris produced by explosive interaction of water and magma
- Can move at speeds of more than 360 km/h

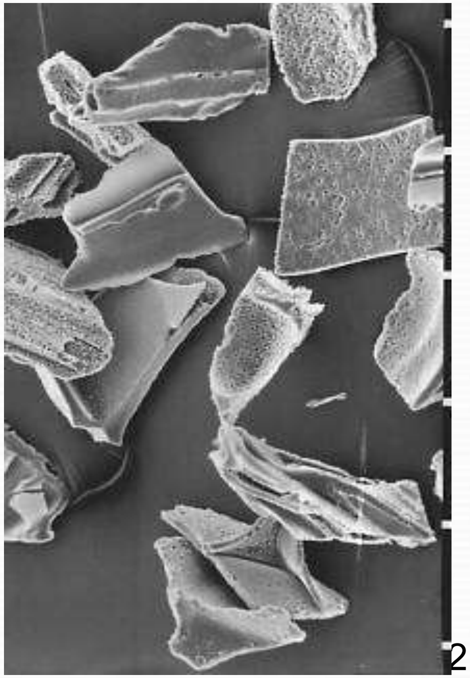
- Lateral blasts

  - Rock fragments, gas, and ash that are blown horizontally from side of volcano

Volcanic Hazards,

- Ash Falls
  - Ash blown high into the atmosphere during a volcanic eruption and then falls over large areas
  - Vegetation may be destroyed
  - Surface water may be contaminated
  - Buildings may be damaged as ash piles up on roofs
  - Health hazards (respiratory illnesses)
  - Mechanical and electrical equipment can be damaged disrupting electrical power
  - Aircraft engines can experience failure

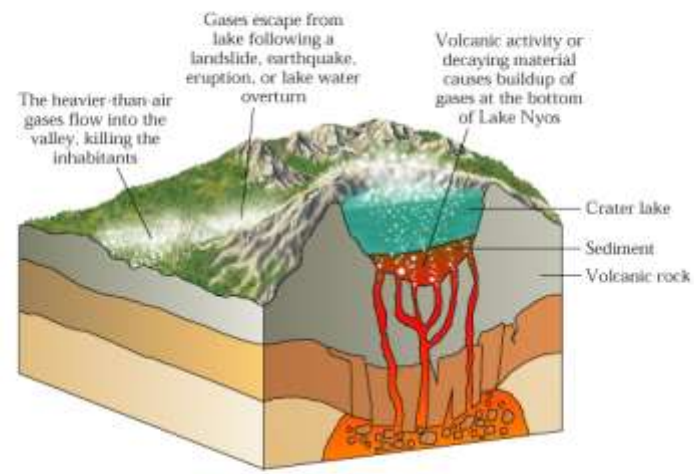




Volcanic Hazards

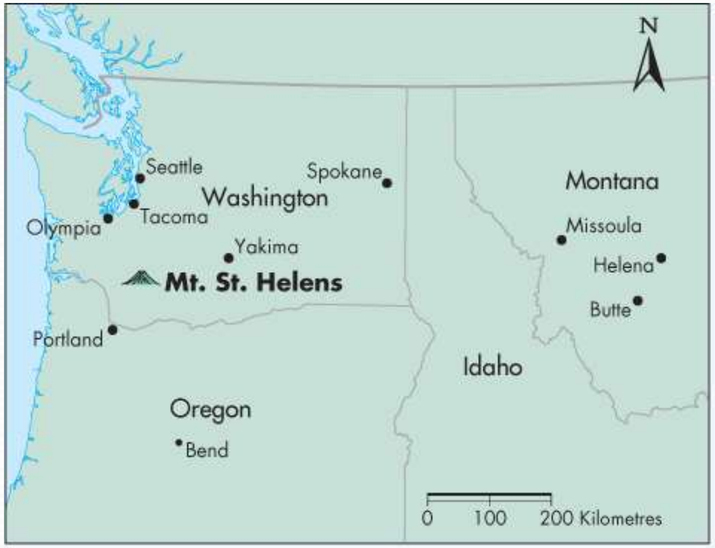
▲ FIGURE 5.35 POISONOUS GAS FROM DORMANT VOLCANO (a) In 1986 Lake Nyos released a large volume of carbon dioxide. (b) The gas asphyxiated 1742 people and about 3000 cattle. (c) Gas being released from the bottom waters of Lake Nyos with a degassing fountain in 2001. (a) © T. Orban/Corbis/ Sygma; (b) © Peter Turnley/Corbis; (c) University of Sussex)

- **Poisonous gases**
  - carbon dioxide, carbon monoxide, sulphur dioxide, hydrogen sulphide, chlorine, hydrofluoric acid
- **Edifice or Sector Collapse**
  - The flank of a volcano may collapse due to ground shaking from steam venting, magma ascent, or an earthquake
- **Debris Flows and Other Mass Movements**
  - Lahars - large amounts of loose volcanic ash and other pyroclastic material become saturated with water and rapidly move downslope



Mt. St. Helens

- Prior to erupting in 1980, it was dormant for 120 years
- In March, 1980 seismic activity and small explosions were observed
- May 1, 1980 – a bulge began to grow on the northern flank of the mountain at rate of 1.5 m per day
- May 18, 1980, 8:32 am – A **M** 5.1 earthquake triggers a landslide/debris avalanche of the bulge area
- Seconds later, a lateral blast from the bulge area occurred at rate of 480 km/h

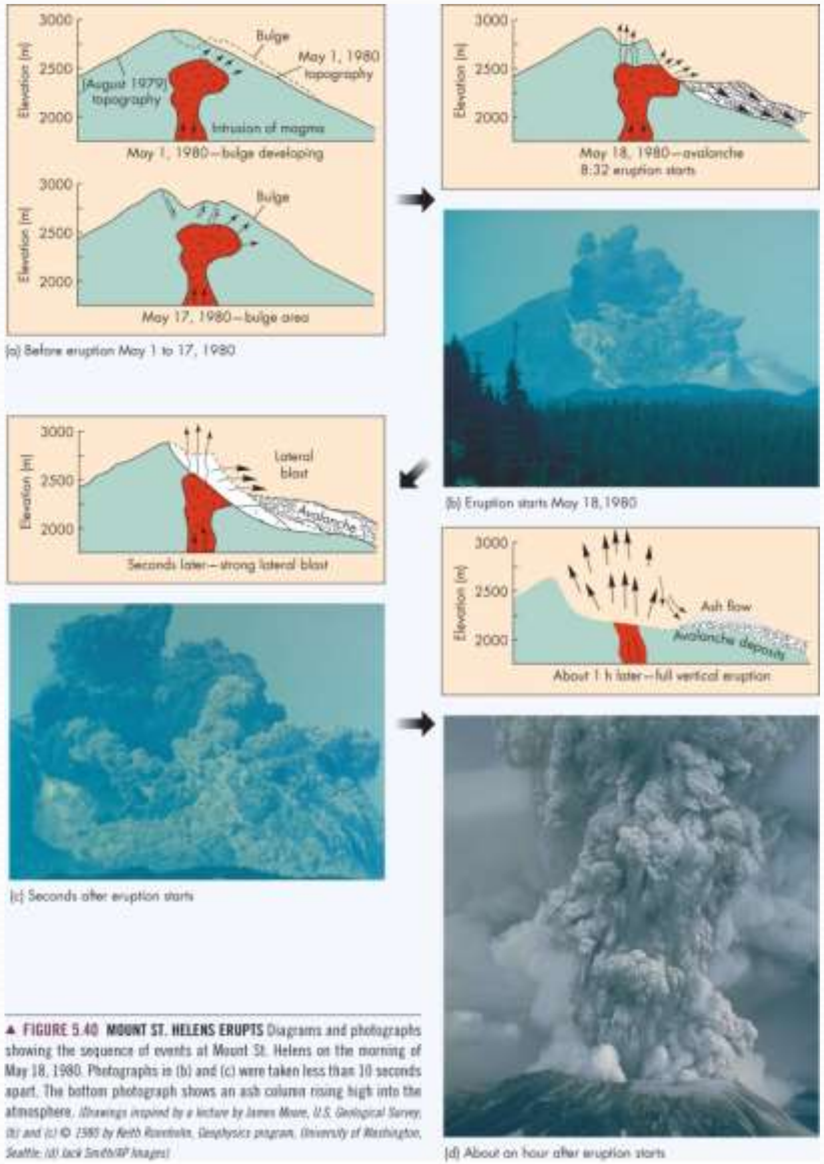


(a)

(b)

◄ **FIGURE 5.39 MOUNT ST. HELENS BEFORE AND AFTER** (a) A map showing the location of Mount St. Helens in Washington State. (b) The volcano before (in photo held aloft) and after the May 18, 1980, eruption. Much of the north side of the volcano slid away during the eruption, and the summit was lowered by about 400 m. The lateral blast shown in Figure 5.40 originated in the amphitheatre-like area at the top centre of the photograph. *((b) Jim Richardson/National Geographic Image Collection)*

Mt. St. Helens Eruption



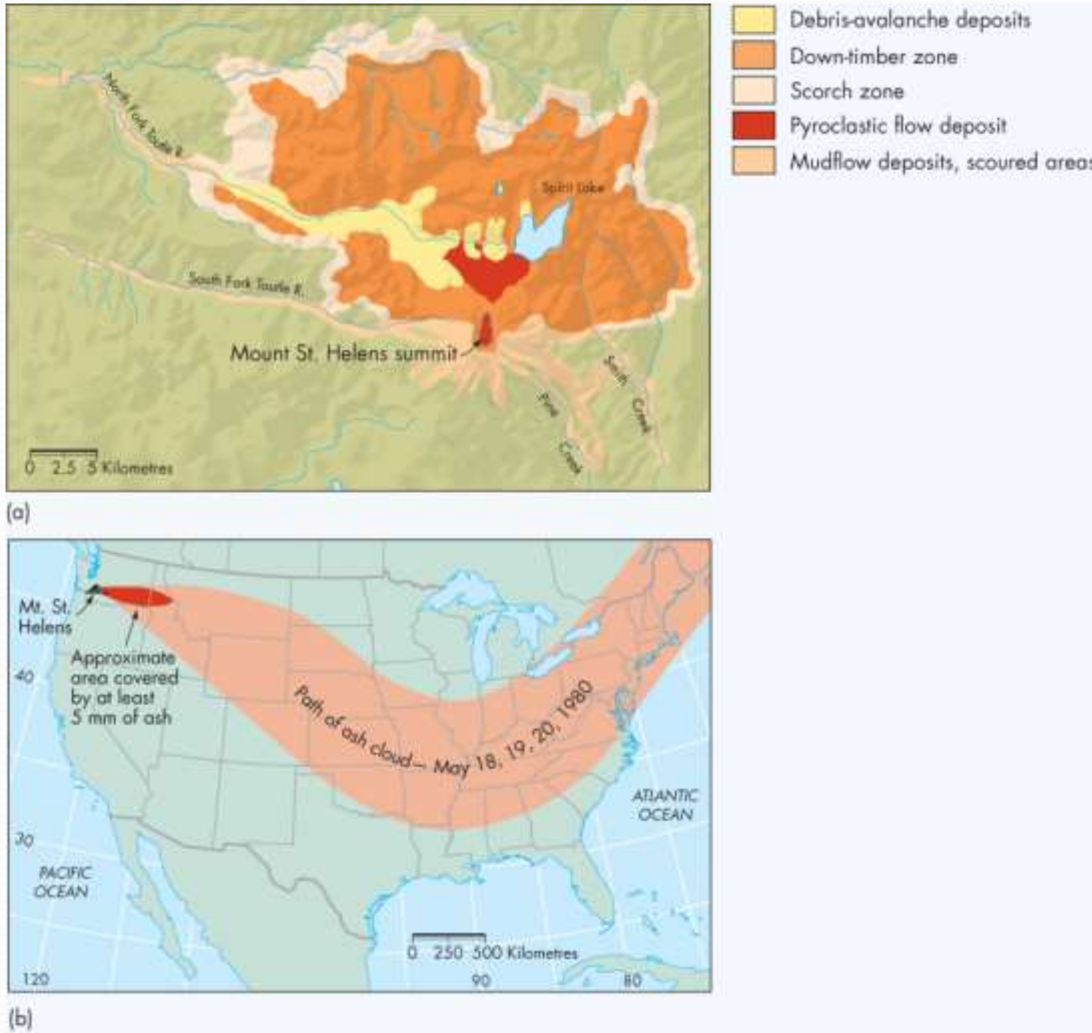
▲ FIGURE 5.40 **MOUNT ST. HELENS ERUPTS** Diagrams and photographs showing the sequence of events at Mount St. Helens on the morning of May 18, 1980. Photographs in (b) and (c) were taken less than 10 seconds apart. The bottom photograph shows an ash column rising high into the atmosphere. *(Drawings inspired by a lecture by James Moore, U.S. Geological Survey; (b) and (c) © 1980 by Keith Ronnholm, Geophysics program, University of Washington, Seattle; (d) Jack Smith/AP Images)*

Mt. St. Helens After the Eruption

- One hour after the blast a vertical cloud of ash extended into the stratosphere

- 9 hours of ash fall covers areas of Washington, northern Idaho, and western Montana.
  - Pyroclastic flows came down the northern slope

- Mudflows occurred at speeds of 55 km/h



▲ **FIGURE 5.41 ERUPTION DEPOSITS AND ASH CLOUD** (a) A map of the area around Mount St. Helens, showing the extents of debris avalanche deposits, tree blow-down, pyroclastic flow deposits, and lahars associated with the May 18, 1980, eruption. (b) The path of the ash cloud (orange) from the 1980 eruption. The area covered by at least 5 mm of ash is shown in red. *(Data are from U.S. Geological Survey publications)*

Mt. St. Helens Eruption -The Aftermath

- 57 people were killed
- Flooding destroyed over 100 homes
- Forests to the north of the mountain were flattened
- Damage exceeded U.S. $1 billion
- September 23, 2004, Mt. St. Helens reawakened
  - Magma began moving up toward the crater floor
  - The mountain is monitored with seismographs to continuously record events

Linkages between Volcanoes and Other Natural Hazards

- Earthquakes
  - Commonly precede or accompany volcanic eruptions
- Landslides
  - Sector collapses can cause tsunamis if they enter water
- Fire
  - Hot lava may ignite plants and structures
- Climate Change
  - Volcanic ash from an eruption can temporarily cool climate

Minimizing the Volcanic Hazard

- **Forecasting** the probability of a volcanic eruption is determined by information gained by:
- Monitoring seismic activity
  - Shallow earthquakes can precede eruptions
  - May not provide enough time for evacuation
- Thermal, magnetic, and hydrologic monitoring
  - Accumulation of hot magma changes temperatures, magnetic properties, and chemical properties of rocks and groundwater

Minimizing the Volcanic Hazard,

- Land surface monitoring
  - Monitoring the growth of bulges or domes
- Monitoring volcanic gas emissions
  - Changes in carbon dioxide and sulphur dioxide emission rates may indicate movement of magma toward the surface
- Geologic history
  - Mapping of lava flows and pyroclastic deposits can be helpful in predicting future eruptive behaviour

Volcanic Alerts

TABLE 5.3 U.S. Geological Survey Volcanic Alert Levels and Aviation Colour Codes[a]

Ground Alert Level	Volcanic Condition	Aviation Colour Code
NORMAL	(1) Typical background, noneruptive state. *Or* (2) If downgraded from higher alert level, activity has ceased and returned to a background, noneruptive state.	GREEN
ADVISORY	(1) Elevated unrest above known background level. *Or* (2) If downgraded from a higher alert level, activity has decreased significantly with close monitoring for possible renewed increase.	YELLOW
WATCH	(1) Heightened or escalating unrest with increased potential of eruption, time frame uncertain. *Or* (2) Eruption underway with limited hazards; for aviation—no or minor volcanic ash emissions.	ORANGE
WARNING	Hazardous eruption imminent, underway, or suspected; for aviation—significant emission of volcanic ash into atmosphere.	RED

[a]Note: For most eruptions, the ground alert level and aviation colour code will be at the same levels; however, for some eruptions there will be a greater hazard on the ground or to aviation and different levels will be assigned for the two environments.

Source: Modified from http://volcanoes.usgs.gov/activity/alertsystem/ and U.S. Geological Survey Fact Sheet 2006-3139.

Perception of Volcanic Risk

- People live near volcanoes for a variety of reasons (ask)
  - Place of birth
  - On some islands, all land is volcanic
  - Fertile land for farming
  - Believe an eruption is unlikely
  - Unaware of risk
  - Economic limitations

Adjustments to Volcanic Hazards

- Bombing
  - Block channels to cause lava flows to take a less damaging route
- Hydraulic chilling
  - Water used to chill and control lava flows
- Wall construction
  - Walls are used to redirect lava flows

(a)

(b)

(c)

◄ **FIGURE 5.49 FIGHTING LAVA FLOWS ON THE ISLAND OF HEIMAEY, ICELAND** (a) A lava fountain as seen from the harbour of Vestmannaeyjar. (b) An aerial view of Vestmannaeyjar. White steam appears above the advancing black lava flow. The steam comes from water being applied to cool and slow the front of the flow. An arcing stream of water from a water cannon is visible in the lower right corner of the photograph. (c) An aerial view showing the front of the blocky lava flow moving into the harbour. *((a) Solarfilma ehf; (b) James R. Andrews; (c) James R. Andrews)*

(a)

(b)

(c)

◄ FIGURE 5.49 **FIGHTING LAVA FLOWS ON THE ISLAND OF HEIMAEY, ICELAND** (a) A lava fountain as seen from the harbour of Vestmannaeyjar. (b) An aerial view of Vestmannaeyjar. White steam appears above the advancing black lava flow. The steam comes from water being applied to cool and slow the front of the flow. An arcing stream of water from a water cannon is visible in the lower right corner of the photograph. (c) An aerial view showing the front of the blocky lava flow moving into the harbour. *((a) Solarfilma ehf; (b) James R. Andrews; (c) James R. Andrews)*

TO DO

- Quizzes and such