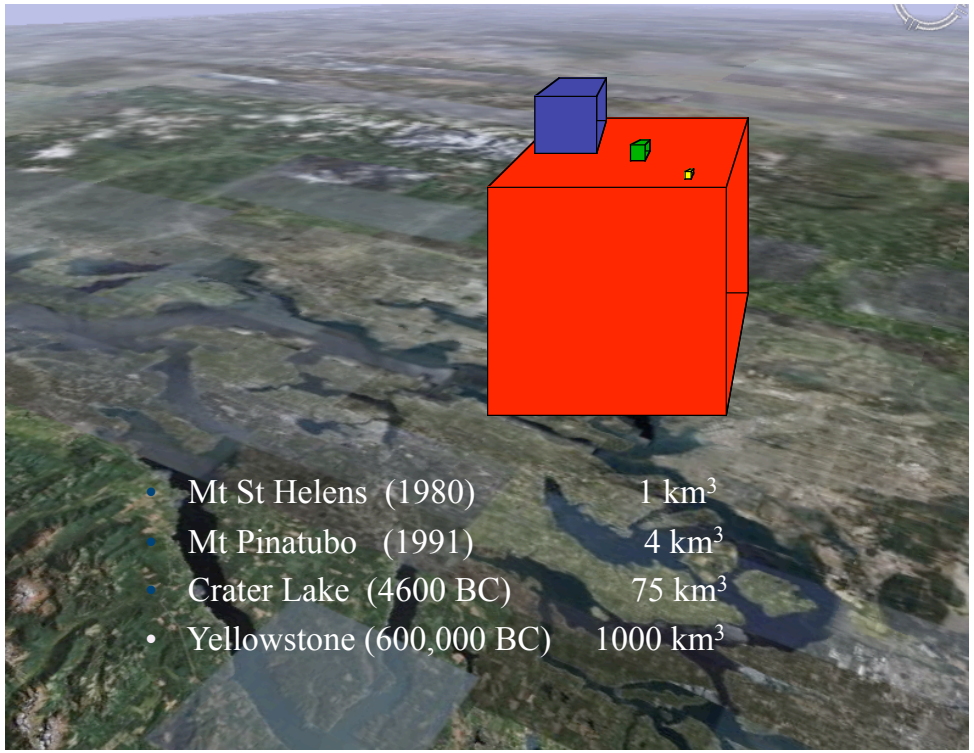
Magma And Volcanoes

Summary

- Magma is molten rock beneath or on the Earth's surface. It also includes any unmelted mineral grains and dissolved gases.
- Magma has a wide range of compositions but silica is always dominates the mix. Magma is characterized by high temperatures and the ability to flow.
- Three kinds of magma predominate: basaltic, andesitic, and rhyolitic. Approximately 80 percent of all magma erupted by volcanoes is basaltic.
- Viscosity is the property of a substance that offers resistance to flow.
- The principal controls on the physical properties of magma are temperature, SiO2 content, and, to a lesser extent, dissolved-gas content. High temperature and low SiO2 content result in fluid magma (basaltic). Lower temperature and high SiO2 contents result in viscous magma (andesitic and rhyolitic magma). Dissolved gas reduces viscosity, but the main controls on viscosity are the SiO2 content and temperature.
- Once formed, magma rises buoyantly because it is less dense than the solid rocks from which it forms.
- All magma contains dissolved gas, mainly water vapor, but also carbon dioxide and other gases. Pressure controls the amount of gas magma can dissolve.
- Gas comes out of solution as magma rises and the pressure decreases.Nonexplosive eruptions are characteristic of low viscosity basaltic magmas. When gas comes out of solution, bubbles form and escape from basaltic magma, in some cases forming spectacular lava fountains.

- Explosive eruptions are characteristic of viscous andesitic and rhyolitic magmas with high gas contents. Gas coming out of solution cannot escape the sticky magma and eventually the bubbles shatter the hot magma into volcanic ash.
- Eruption columns of densely mixed hot volcanic gas and tephra can result from explosive eruptions. Such eruptions are called Plinian eruptions.
- When a mixture of volcanic gas and pyroclasts in an explosive eruption is more dense than air, the mixture flows down the side of the volcano as a pyroclastic flow.
- In some cases the first blast of an explosive eruption is sideways, a lateral blast. The eruption of Mount St. Helens in 1980 started with a devastating lateral blast.
- Volcanoes either erupt from a central vent of from an elongate fissure.
- The sizes and shapes of central vent volcanoes depend on the kind of material erupted, viscosity of the lava, and explosiveness of the eruptions.
- Viscous magmas erupt a lot of tephra and tend to build steep-sided tephra cones or stratovolcanoes.
- Low-viscosity magmas low in SiO_2 tend to be erupted form central vents as fluid lavas that build gently sloping shield volcanoes. When such magma is erupted from a fissure the result is a lava plateau.

- Near the summit of most central vent volcanoes is a crater formed by a combination of eruption and collapse of the steep-sided walls.
- Calderas are created by the collapse of the roof of a volcano into the underlying magma chamber following a major eruption.
- Fissure eruptions form plateau basalts with low viscosity magma, and ash-flows with high viscosity magma. Submarine fissure eruptions form pillow basalts.
- Low viscosity eruptions are not dangerous to humans, though they can overrun buildings and landscapes. High viscosity tephra eruptions are very dangerous.
- As a result of population pressure, an increasing number of people live in harms way from volcanos



Major Questions

- What is the connection between volcanos and plate tectonics?
- Why are many volcanos aligned?
  - Island Arcs
  - Linear Chains
- Why are some volcanos isolated?
  - "Hot Spot" volcanos
- What controls the appearance of volcanos?
  - Stratovolcanos
  - Shield Volcanos
  - Caldera Volcanos
- Which volcanos are (relatively) safe?
  - And which are extraordinarily dangerous?

Types of Volcanos

- Stratovolcano
  - Steep sided, Mixture of lava and pyroclastic material
  - Commonly andesite composition
  - Subduction related
- Shield/Fissure Volcanos
  - Spreading Centers, Hot spots, Rift zones, and Subduction zones
  - Basaltic composition - 80%+ of all volcanos
- Large Calderas
  - Large depressions 30 to 100s of km across
  - Rhyolite composition
  - Very explosive (ash deposits)

Tectonic Settings of Volcanos

- Subduction Zones
  - Island Arcs and linear chains
  - Stratovolcanos - composite cones dominated by Andesite composition
- Spreading Centers
  - Fissure eruptions - Basaltic composition
  - most active systems in world but not easily monitored
- Hot Spots
  - Shield volcanos (oceanic) Caldera eruptions (continental)
  - Traced of extinct volcanos extend from active center
  - May originate at Core-Mantle Boundary
  - "Plume Initiation" a truly catastrophic event

Magma Questions

- Where does magma originate?
- What controls magma composition?
- What controls magma viscosity?
- How does magma reach the surface?
  - What happens if it does not?

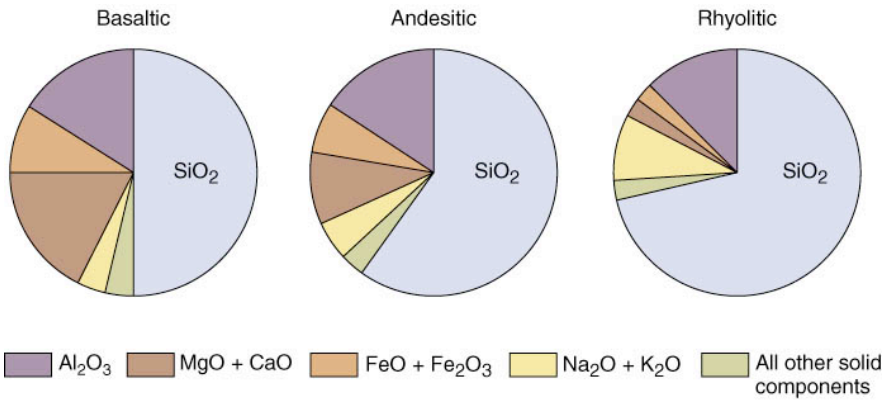


Figure 5.1

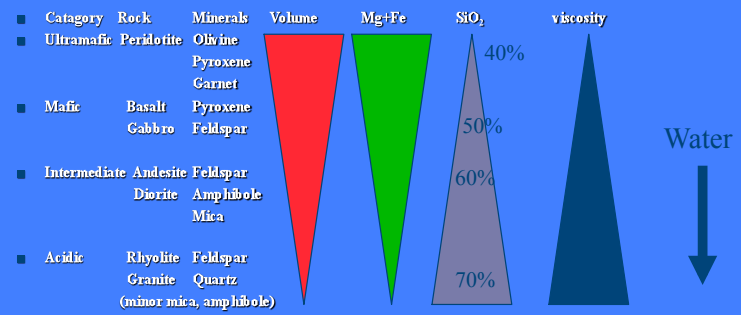
Evolution of Magma
The Important Ideas

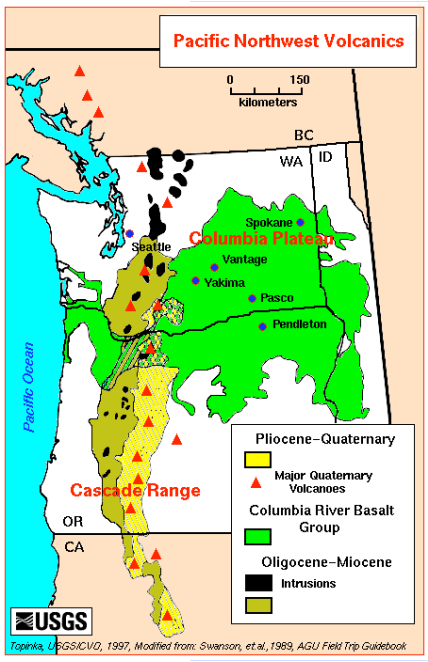
- Rocks melt over a range of temperature
  - minerals have differing melting temperatures
- Partial melts differ in chemical composition from the residual rock
- Fractionation is the process of separating melt from the residual rock

Evolution of Magmas
The Process

- Starts in the mantle
  - partial melt (<10%) basaltic composition
  - depths of near 100 km
  - melt is less dense than mantle - thus it rises
- Processed in the Crust
  - Further fractionation (partial solidification)
  - Mixed with crustal rocks that are melted
  - Water is important – lowers melting point
- Not all reaches surface
  - Plutonic:Volcanic = 10:1

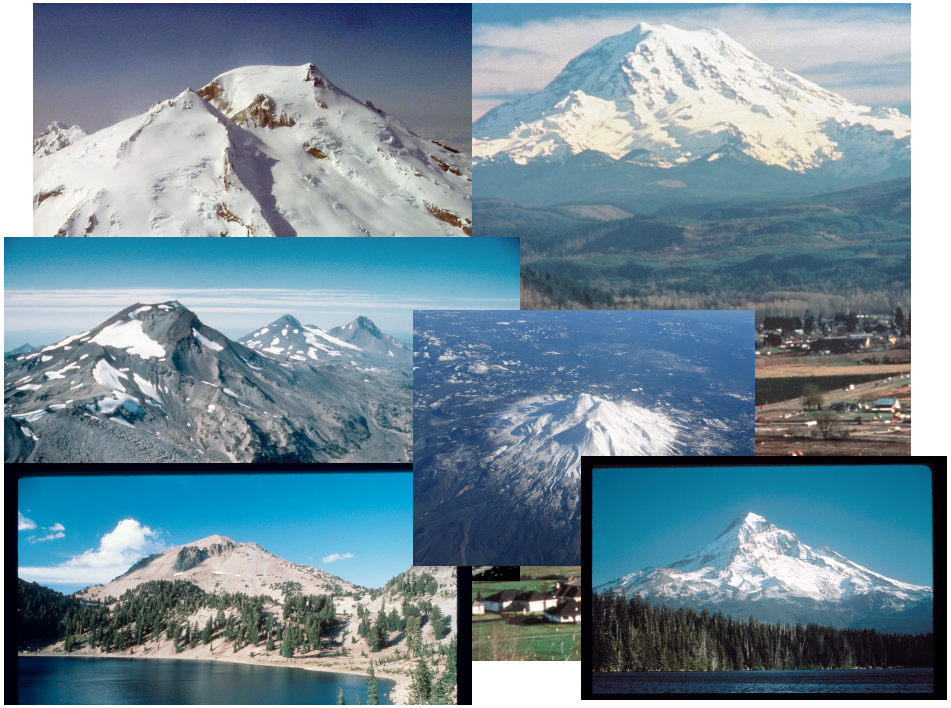
Melt Fractionation

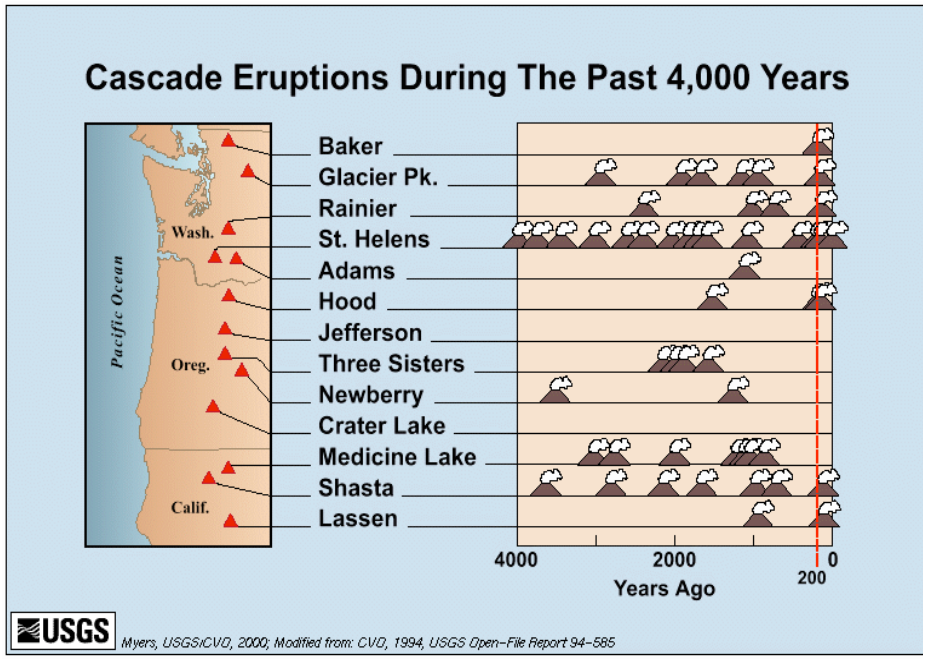




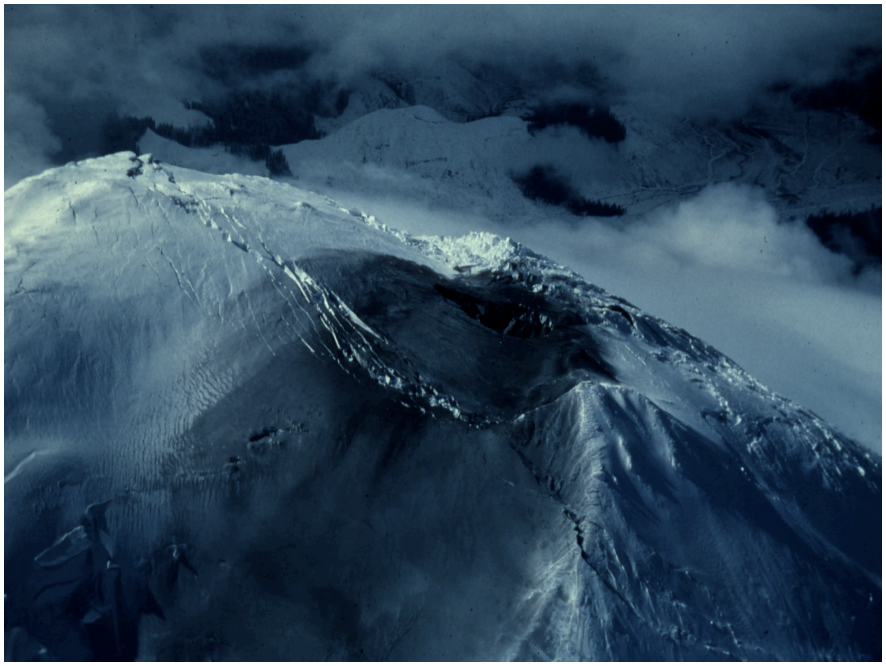
Northwest Issues

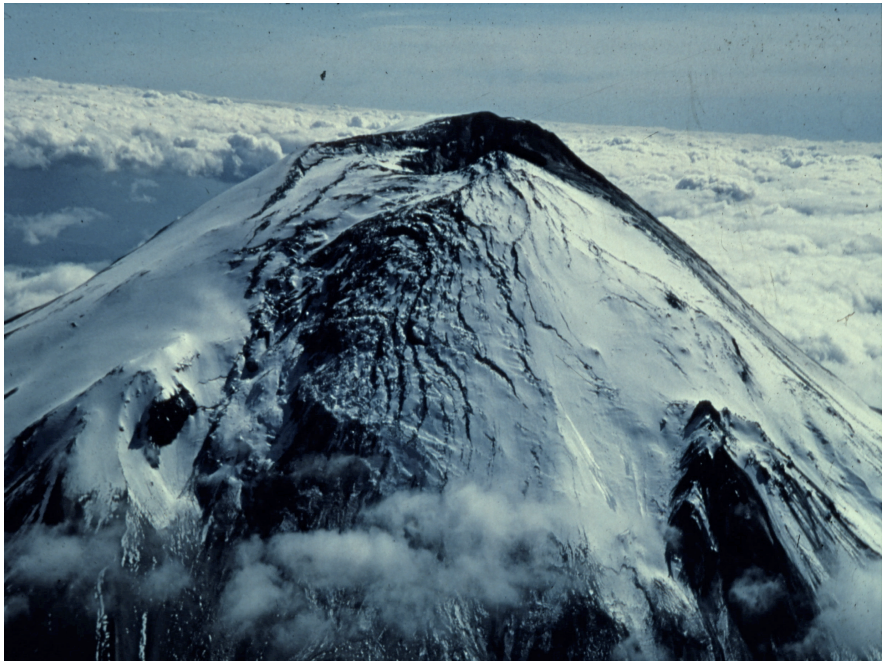
- The Stratovolcanos
  - Where are they?
  - How likely are eruptions in our lifetime?
  - Other hazards associated with the volcanic structures?
- Columbia River Basalt Flows
  - location and extent?
  - cause?
  - structure of flows and environmental impact
- Cascade Batholiths
  - Why does California have more "good" rock climbing than Washington?




Cascade Eruptions During The Past 4,000 Years
Pacific Ocean
Wash.
Oreg.
Calif.
Baker
Glacier Pk.
Rainier
St. Helens
Adams
Hood
Jefferson
Three Sisters
Newberry
Crater Lake
Medicine Lake
Shasta
Lassen
4000
2000
0
200
Years Ago
USGS
Myers, USGS/CVO, 2000; Modified from: CVO, 1994, USGS Open-File Report 94-585


USGS



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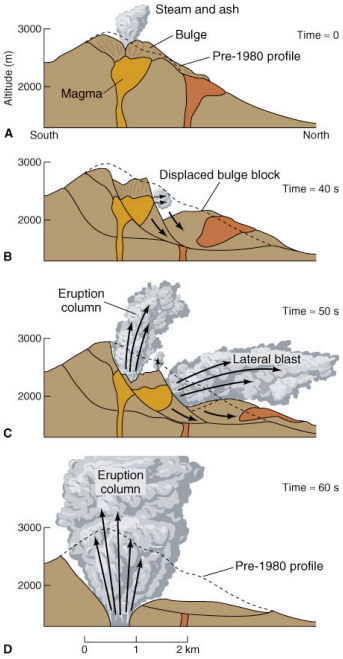
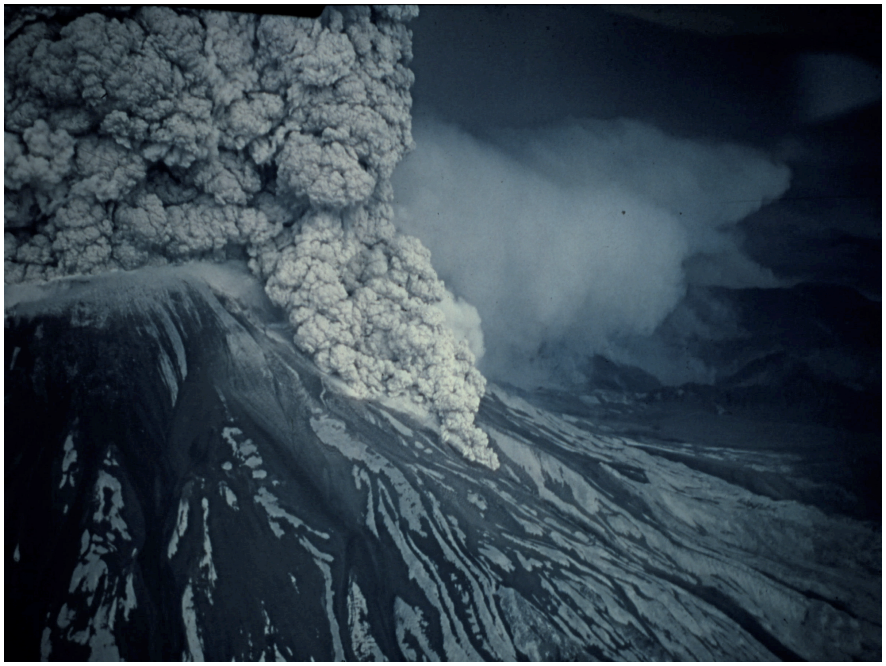

Steam and ash
Bulge
Time ≈ 0
Pre-1980 profile
Magma
Altitude (m)
3000
2000
A
South
North
Displaced bulge block
Time ≈ 40 s
B
Eruption column
Time ≈ 50 s
Lateral blast
C
Time ≈ 60 s
D
0
1
2 km

Figure 5.10



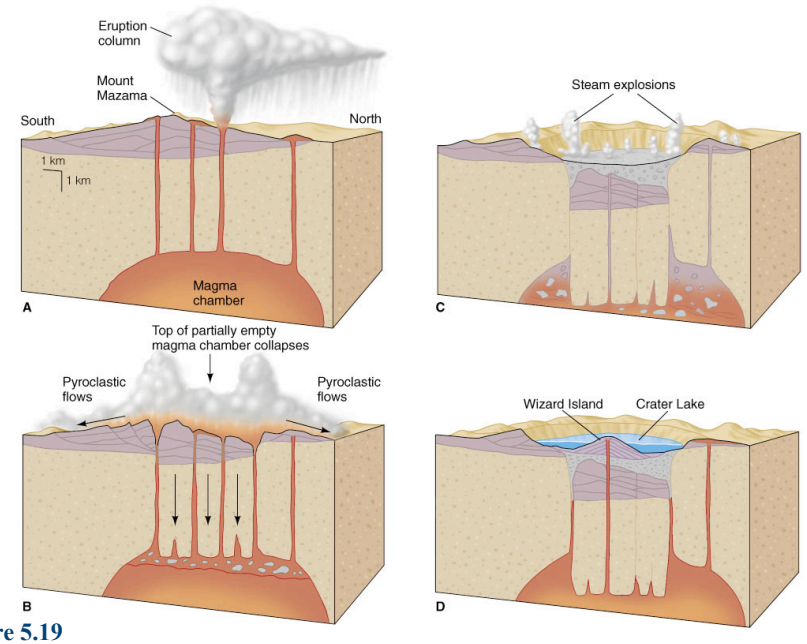
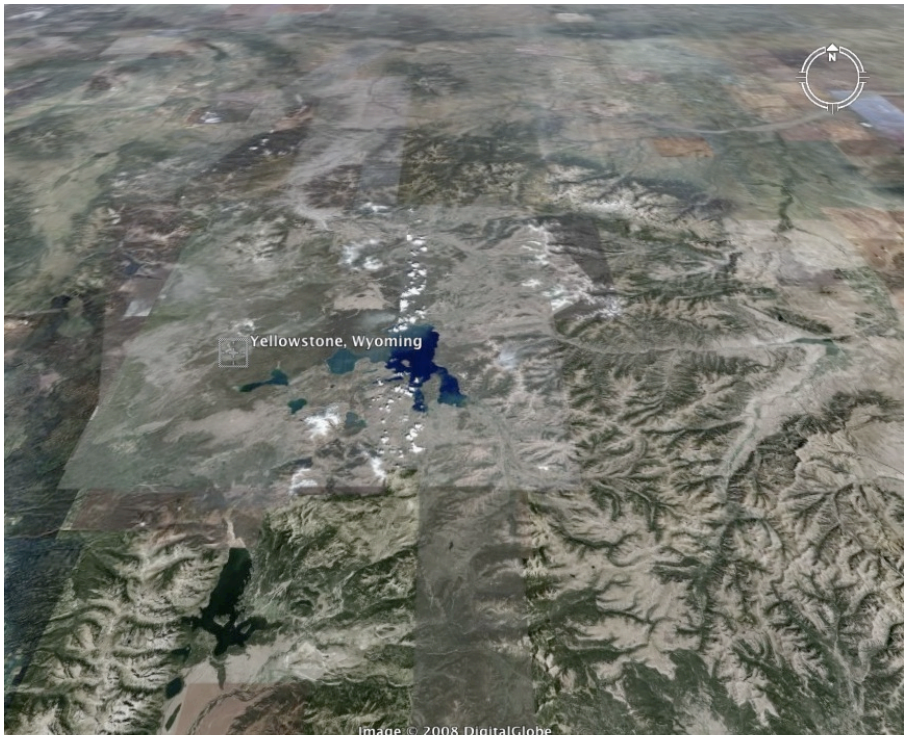

Eruption column
Mount Mazama
South
North
1 km
1 km
Magma chamber
A
Steam explosions
C
Top of partially empty magma chamber collapses
Pyroclastic flows
Pyroclastic flows
B
Wizard Island
Crater Lake
D

Figure 5.19


Yellowstone, Wyoming
Image © 2008 DigitalGlobe

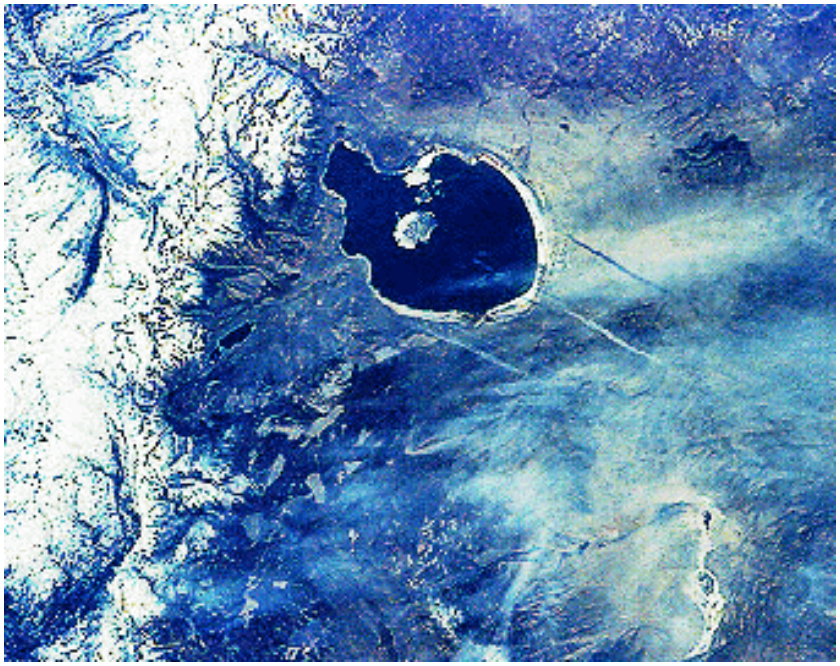


Figure 5.18

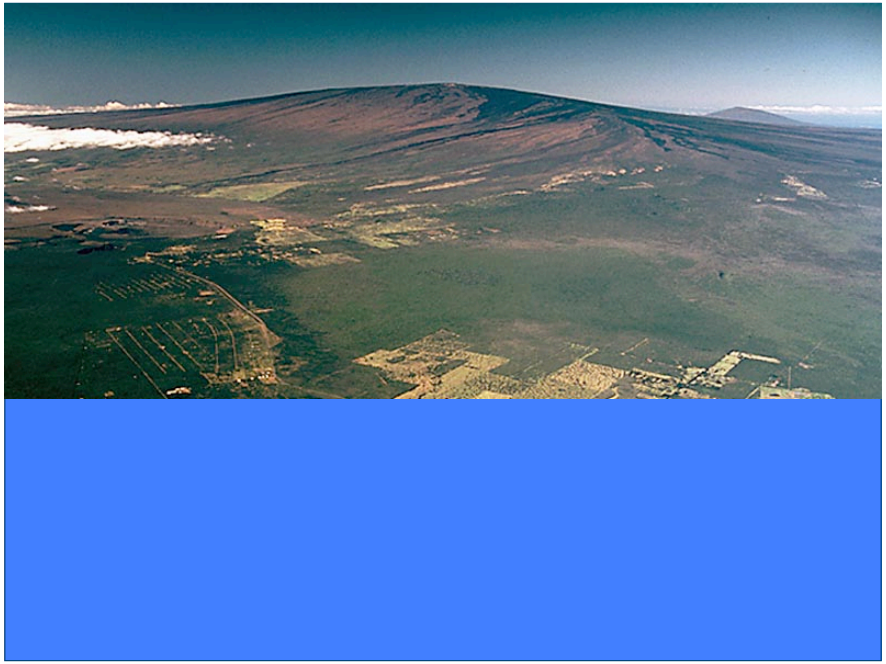


Figure 5.11

Figure 5.13

Figure 5.21

Figure 5.3

Magma Facts

- All magma contains small amounts of dissolved gas.
  - Water and CO2 are 98% of the gas.
  - More can be dissolved at higher pressure
- Typical magma temperatures are 1000 to 1200°C
- Viscosity depends on T and silica content
  - Rhyolite>andesite>basalt
  - Explosive potential depends on gas content and viscosity
- Magma is buoyant

Explosive Eruptions

- Pumice: gas comes out of solution with pressure drop.
- viscous magma will shatter the magma into tiny fragments called volcanic ash.
- Volcanic ash is the most abundant product of explosive eruptions.

Posteruption effects

- When active volcanism finally ceases, rock in and near an old magma chamber may remain hot for hundreds of thousands of years.
- Thermal spring at many volcanic sites (Italy, Japan, and New Zealand) have become famous health spas and sources of energy.
  - A thermal spring that intermittently erupts water and steam is a *geyser.*
    - Most of the world's geysers outside Iceland are in New Zealand and in Yellowstone National Park.

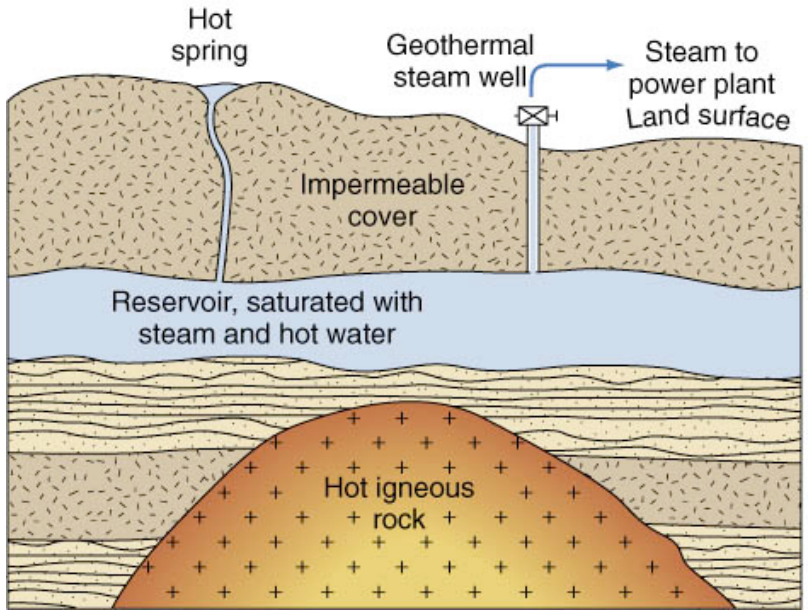


Figure B5.2

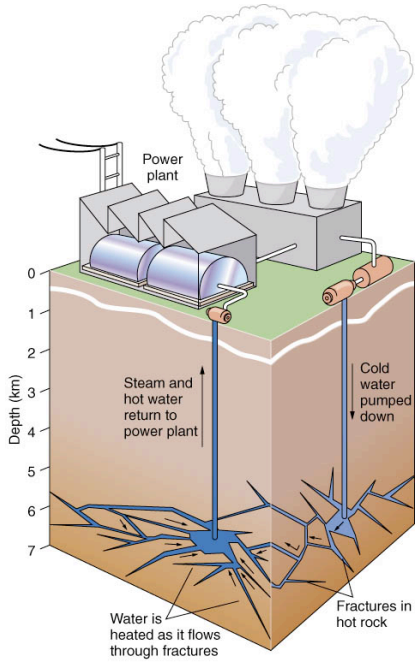


Figure B5.3

Volcanic Hazards

- Hot, rapidly moving pyroclastic flows and laterally directed blasts can overwhelm people before they can evacuate.
  - Mont Pelee in 1902 and Mount St. Helens in 1980.
- Tephra and hot poisonous gases can bury or suffocate people.
  - 79 Mount Vesuvius in A.D. 79.

Volcanic Hazards

- Mudflows, called *lahars,*
  - In 1985, the Colombian volcano Nevado del Ruiz experienced a small, nonthreatening eruption. But, when glaciers at the summit melted, massive mudflows of volcanic debris moved swiftly down the mountain , killing 20,000.
- Violent undersea eruptions can cause *tsunamis.*
  - Krakatau, in 1883, killed more than 36,000 on Java and nearby Indonesia islands.
- A tephra eruption can disrupt agriculture, creating a famine.

Figure 5.24

Figure 5.25