Volcanism and Volcanoes

- **Volcanism is one of the most impressive displays of Earth's dynamic internal processes.**
- **From a human perspective, volcanism can be a destructive force causing property damage, injuries, fatalities, and atmospheric changes.**
- **From a geologic perspective, volcanism is a constructive process that builds oceanic islands, produces oceanic crust, provides parent material for highly productive soils, and releases the gases that formed Earth's early atmosphere and surface waters.**

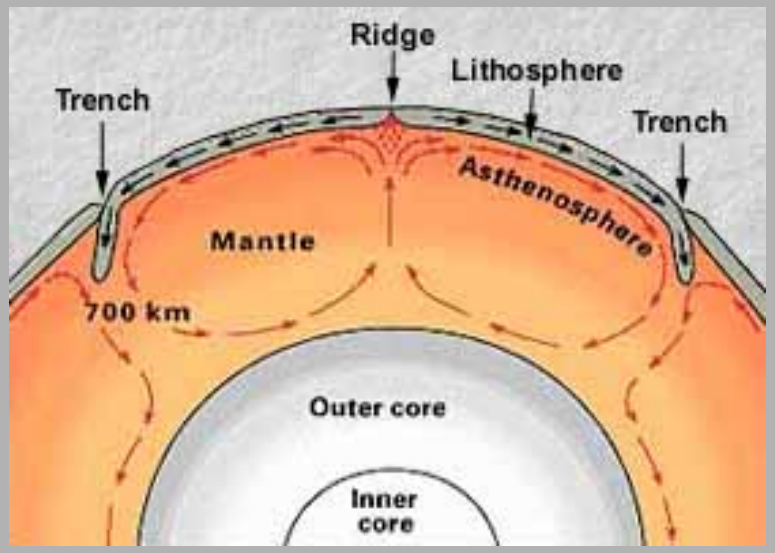
Redoubt Volcano. Photograph by W. White, U.S. Geological Survey, December 18, 1989

Why Study Volcanism?

- Volcanic eruptions affect the atmosphere, hydrosphere, and biosphere locally and sometimes globally.
- Volcanism is a major geologic hazard to a significant portion of Earth's inhabitants.
- Volcanism is responsible for much of Earth's most spectacular scenery.

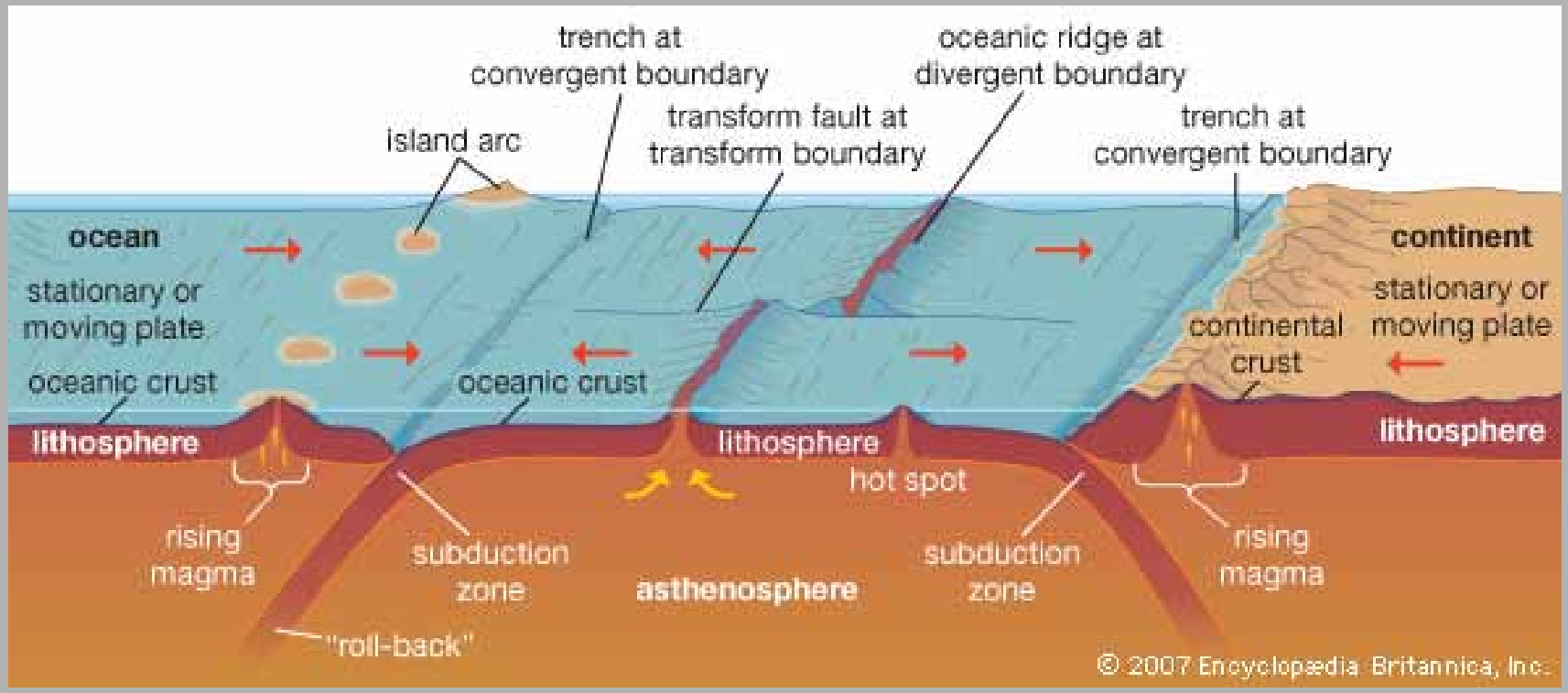
Augustine Volcano. Photograph by M.E. Yount, U.S. Geological Survey, March 31, 1986.

First, you need to know a little about Plate Tectonics..



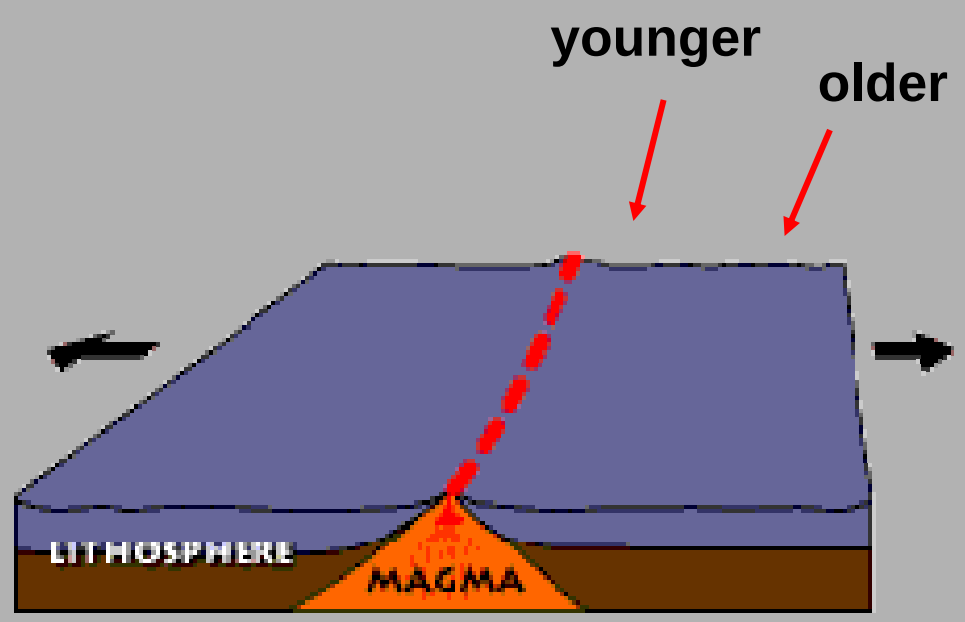
Text: Figure 4.1, pg 107

http://www.geology.sdsu.edu/how_volcanoes_work/Volcano_tectonic.html



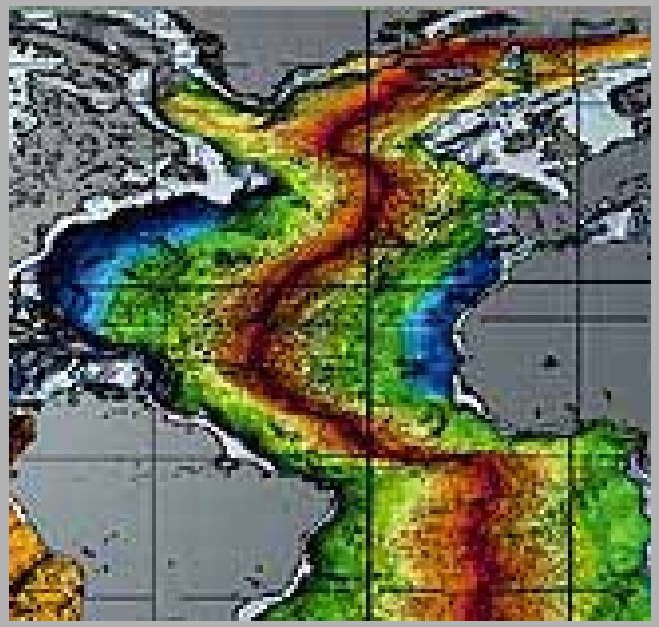
Convergent, Divergent and Transform Boundary

http://geomaps.wr.usgs.gov/parks/pltec/pltec3.html



DIVERGENT BOUNDARY

Divergent Plate Boundary



Age of the Atlantic oceanic crust. The crust near the continental margins (blue) is about 200 million years old. It gets progressively younger toward the mid-Atlantic ridge, where oceanic crust is forming today. *Courtesy of NOAA*

http://www.geology.sdsu.edu/how_volcanoes_work/Volcano_tectonic.html

Pillow basalts on the south Pacific seafloor --
Courtesy of NOAA.

http://www.geology.sdsu.edu/how_volcanoes_work/Volcano_tectonic.html

Transform Boundary…earthquakes

Convergent Plate Boundary

- The Pacific Ring of Fire
- the most volcanically active belt on Earth
- subduction zone…large ocean trenches

Island Arc

Volcanic Arc

http://www.geology.sdsu.edu/how_volcanoes_work/Volcano_tectonic.html

Intraplate Volcanism

Mantle plumes on earth

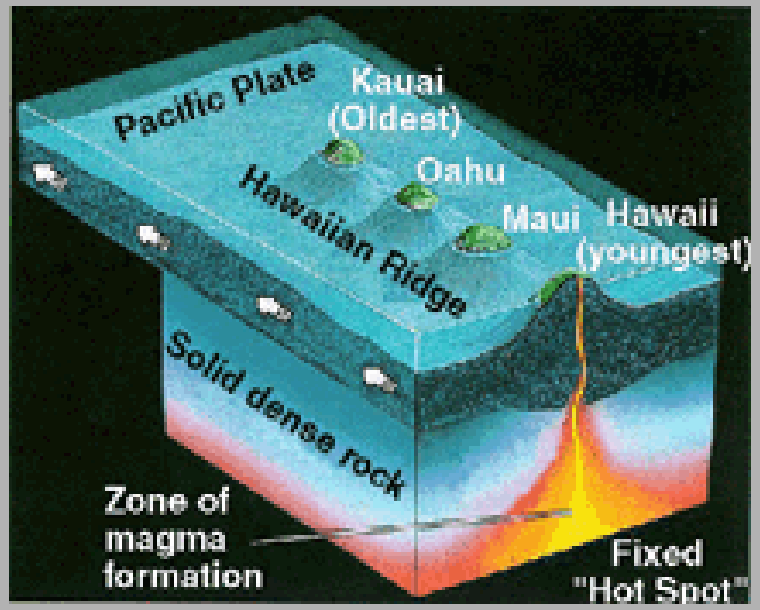


Figure 4.4 pg. 109 text

Hotspot Volcanism

http://www.geology.sdsu.edu/

Hazards….

- As well as the immediate hazard from ashfalls, mudflows and lava, volcanoes have the potential to influence global climates. The concentration of volcanoes in the northern hemisphere places it at greater risk

Ascending eruption cloud from Redoubt Volcano. Photograph by J. Warren, April 21, 1990. U.S. Geological Survey Digital Data Series DDS-39

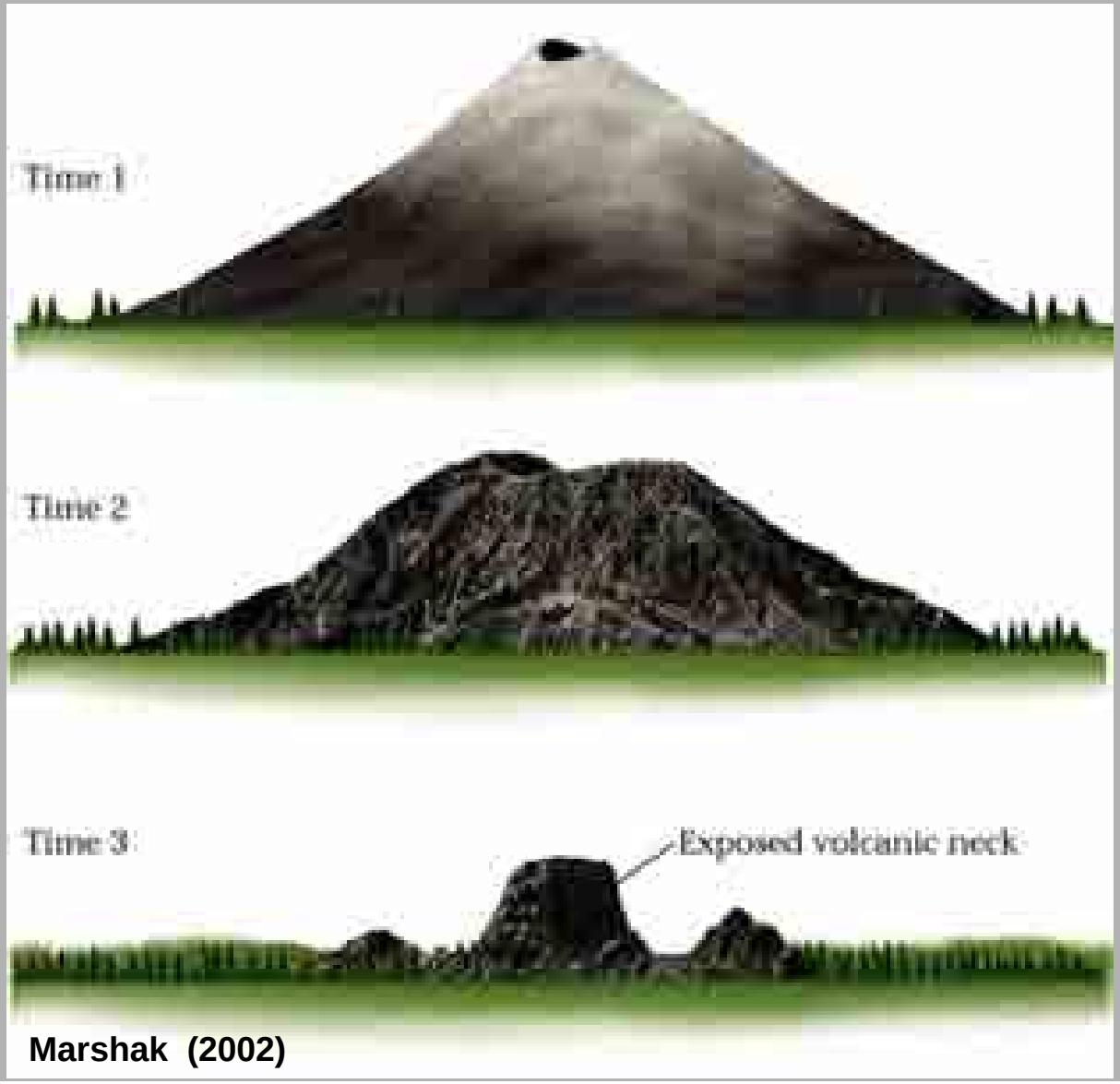
Volcanism

Volcanism: the extrusion of lava (and the gases it contains) and the ejection of pyroclastics onto the Earth's surface or into the atmosphere, as well as the formation of volcanoes and extrusive igneous rocks by these processes.

- Active volcanoes: erupted recently, or within recorded history.
- Dormant volcanoes: have not erupted in recorded history, but are fresh looking (not eroded), and may erupt in the future.
- Extinct volcanoes: have not erupted in recorded history, are deeply eroded, and are unlikely to erupt in the future.

Kilauea, Hawaii, Wicander and Monroe (2002)

Active, dormant or extinct?



Marshak (2002)

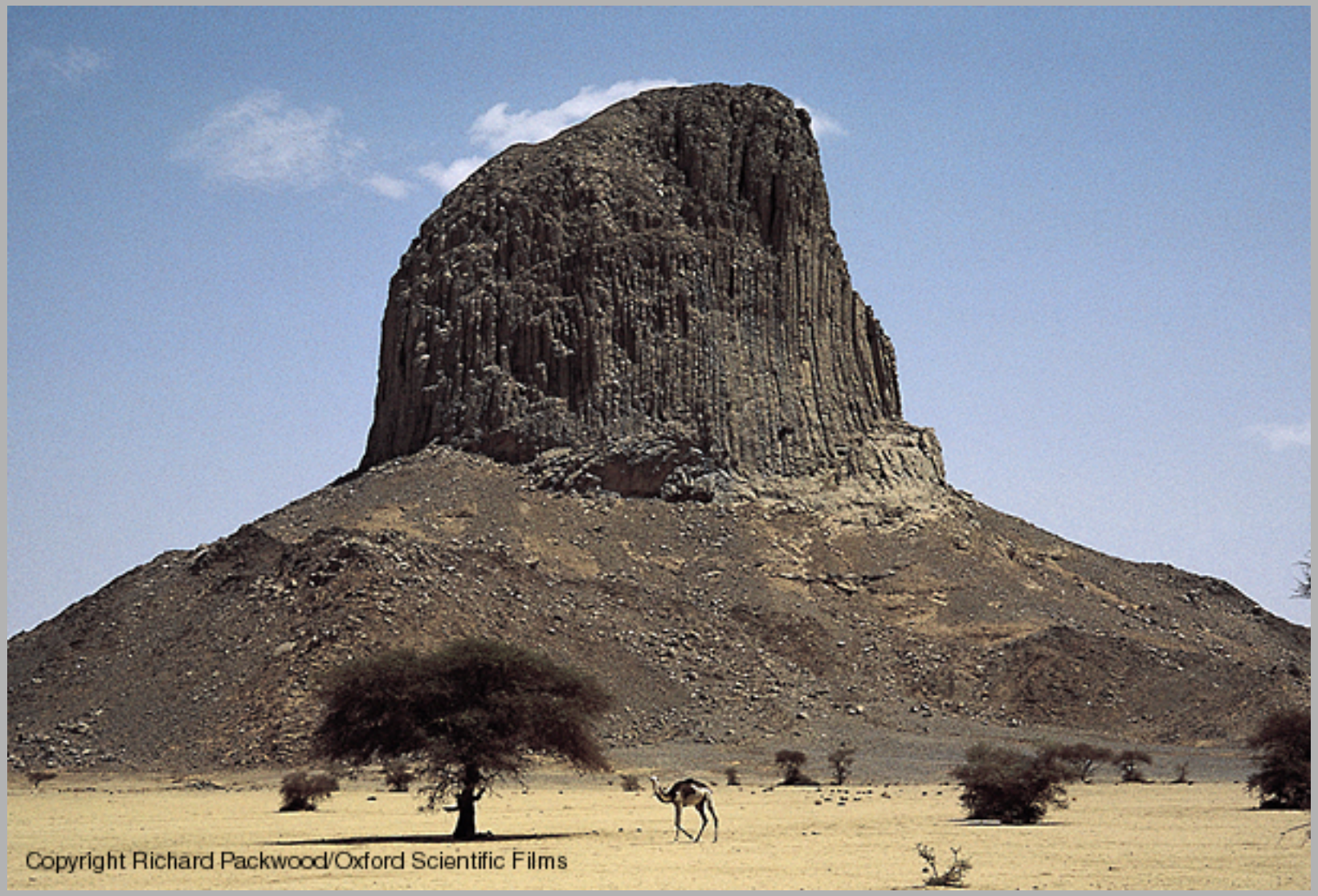
Active volcano

White Island, New Zealand

Dormant volcano

Vulcan Olca, Bolivian border, Collahuasi

Extinct volcano



Murck and Skinner (1999)

Volcanism

- Volcanism takes many forms but basically it comes in two:
  - Explosive or non-explosive
- Magma composition is the key
- Siliceous magmas are viscous and can retain more gas, consequently they erupt more violently than basaltic magmas

Classifying volcanoes

- **Geological classifications**
  - **The viscosity of a magma or lava is critical to its explosivity. In general the higher the temperature the less viscous the lava, however the composition (specifically SiO_2) is also critical.**
- **A somewhat more systematic method is the Volcanic Explosivity Index (VEI)**

Volcanic explosivity index

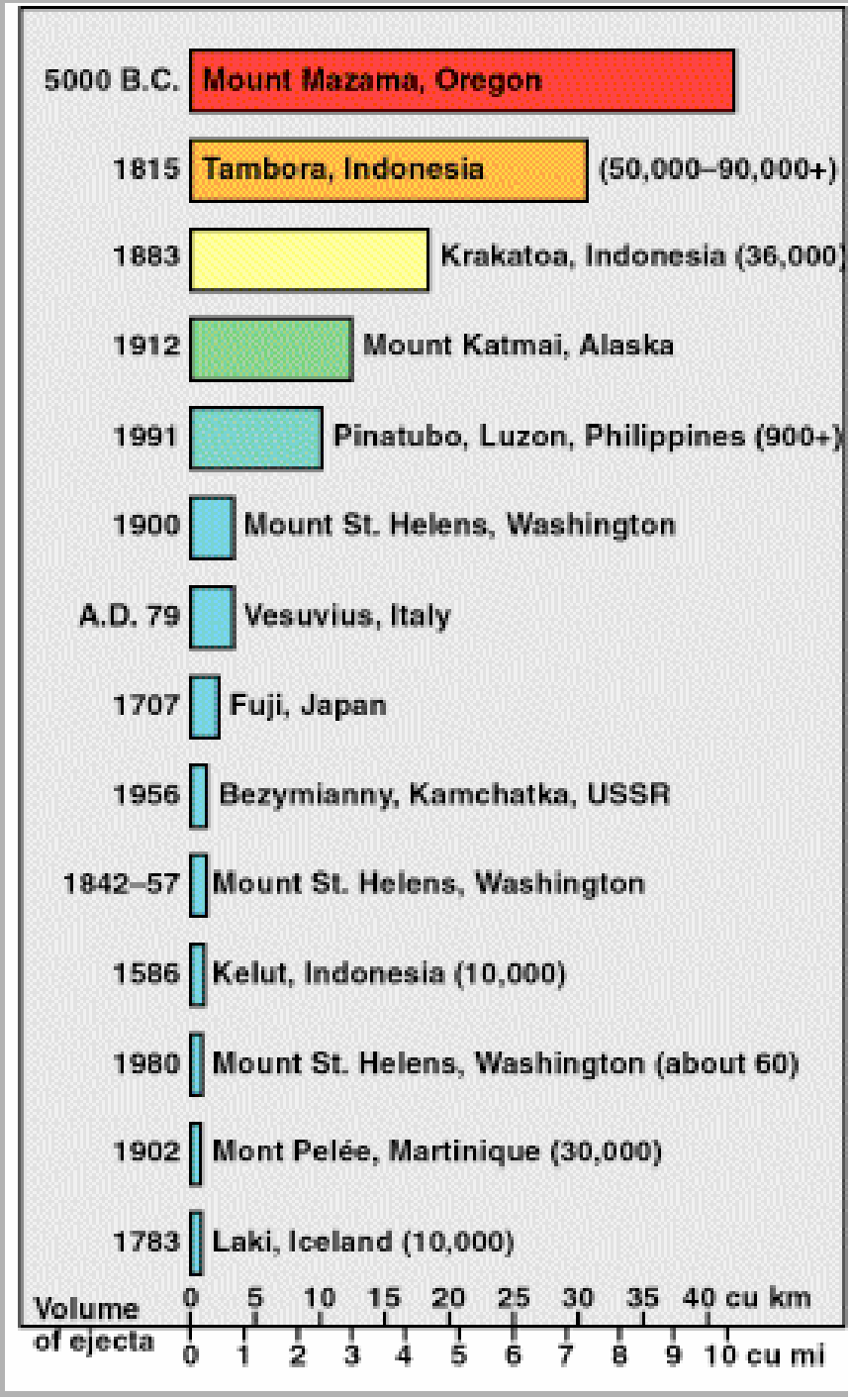
VEI	Description	Plume Height	Volume Ejected	Duration of Blast	Global Frequency
0	non explosive	0-100m	1000s m^3	<1	daily
1	gentle	100-1000s	10,000s m^3	<1	daily
2	explosive	1-5 km	1,000,000s m^3	1-6	weekly
3	severe	3-15 km	10,000,000s m^3	1-12	yearly
4	cataclysmic	10-25 km	100,000,000s m^3	1-12	decades
5	paroxysmal	> 25 km	1 km^3	6-12	centuries
6	colossal	> 25 km	10s km^3	>12	centuries
7	supercolossal	> 25 km	100s km^3	>12	1000s of yrs
8	megacolossal	> 25 km	100s km^3	>12	10,000s of yrs

Volcanic Explosivity Index

- The volcanic explosivity index (VEI) ranks eruptions based on combined intensity and magnitude.
- The higher the VEI, the more explosive the eruption.
- Height of the eruption plume, volume of explosively ejected material, and duration of eruption are the criteria for assessing VEI.
- Of the 3,300 historic eruptions, 42% lasted less than a month. A significant number (33%) of eruptions lasted from 1-6 months. A few volcanoes (16), such as Stromboli and Mount Etna of Italy, have erupted continuously for over 20 years.
- Unfortunately, of 252 explosive eruptions, 42% erupted most violently in the first day of activity.

V.E.I

The Mt St Helens eruption, although quite violent was actually fairly small



Montgomery (2001)

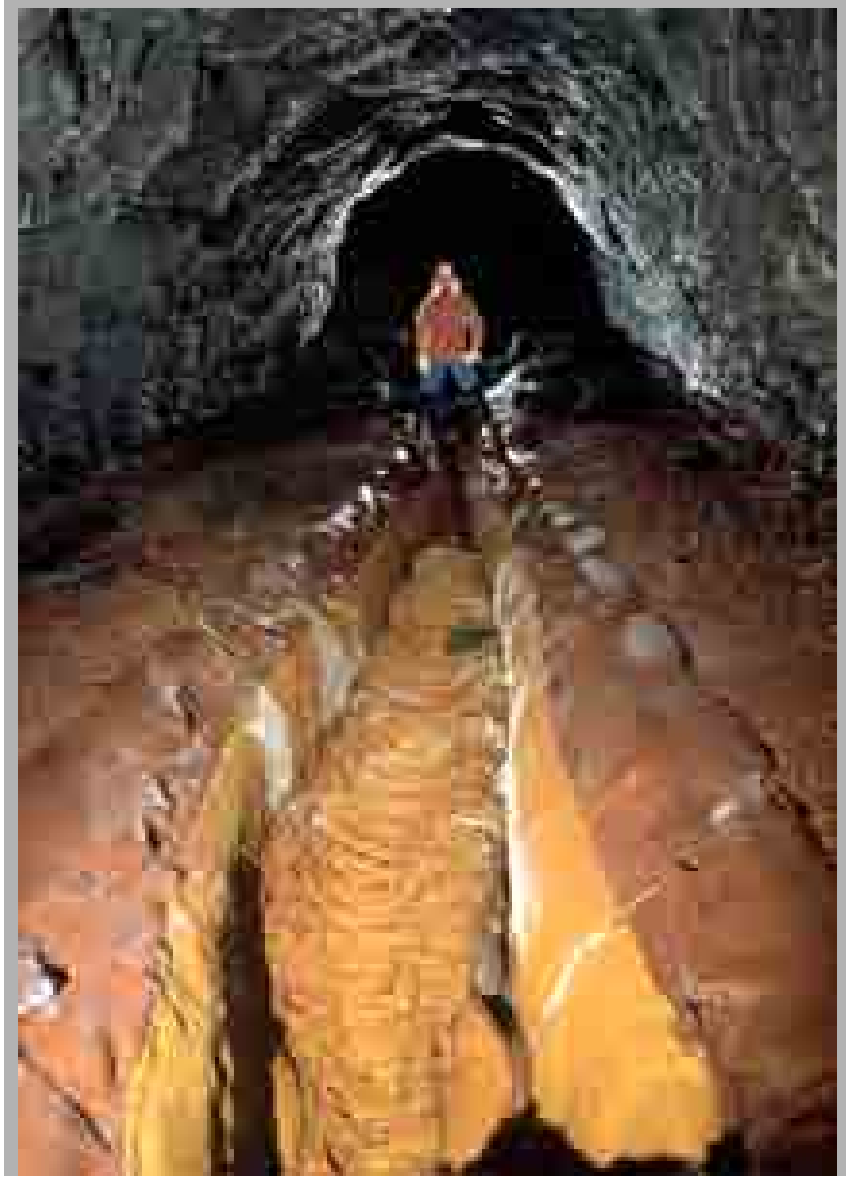
Volcanism - Volcanic Gases

Most (50-80%) of the gas emitted by volcanoes is water vapor. Lesser amounts of carbon dioxide, nitrogen, sulfur dioxide, and hydrogen sulfide are also released.

Most gases quickly dissipate, but on occasion have had negative local or regional (Blue Haze Famine, Lake Nyos) effects and in some cases even significant global consequences (Tambora, Krakatau).

Mt. Lassen, California, Wicander and Monroe (2002)

Volcanism - Lava Flows

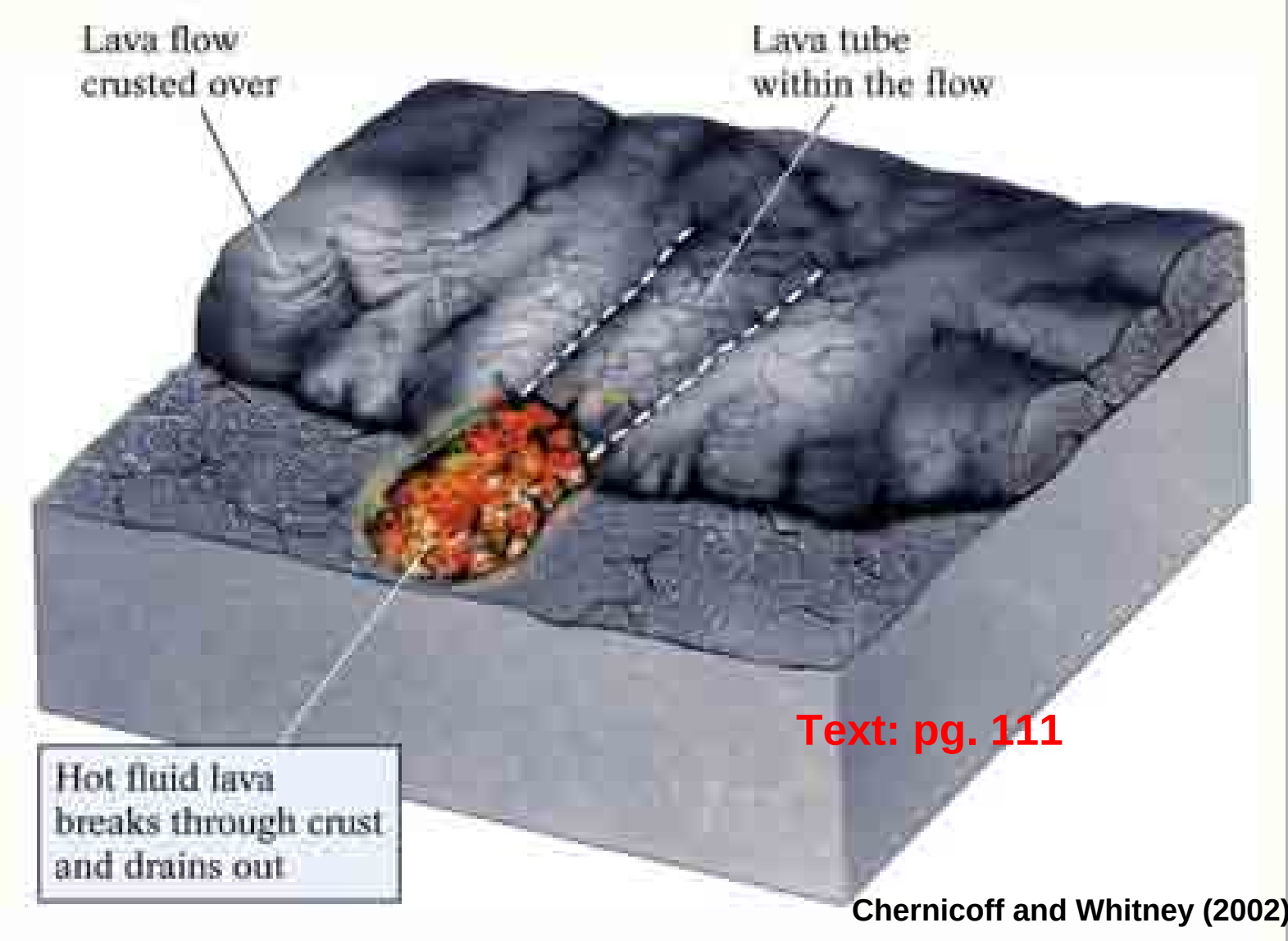


Lava flows are generally slow moving. However, lava can move at speeds in excess of 50 km/hr in lava tubes.

Lava tubes form conduits beneath the surface of a lava flow when the sides and top of the flow have solidified. When the eruption ceases, the tube drains, leaving an empty, tunnel-like structure.

Lava tube in Big Red Cave, Hawaii. Photo by Dave Bunnell, NSS News v60, June 2002

Lava tube formation



Text: pg. 111

Chernicoff and Whitney (2002)

Lava Flows

Pahoehoe lava has a ropy surface much like that of taffy. This type of surface forms when the lava is low viscosity (relatively runny).

Page 110 text

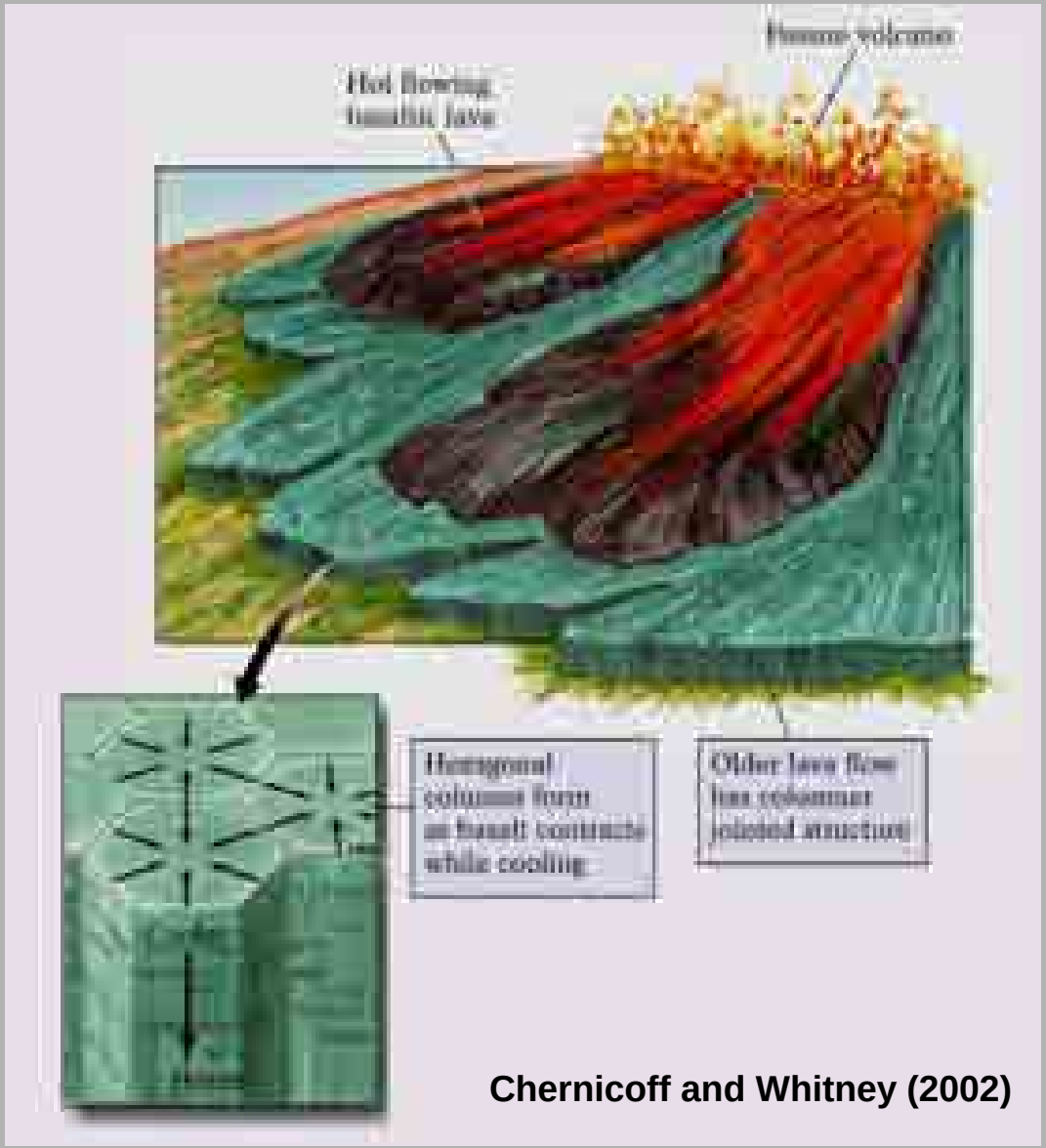
Aa lava has a jagged, rough surface. Due to its high viscosity, this lava breaks into angular blocks as it flows.

Wicander and Monroe (2002)

1 Ga pahoehoe flows

Basaltic lava flow

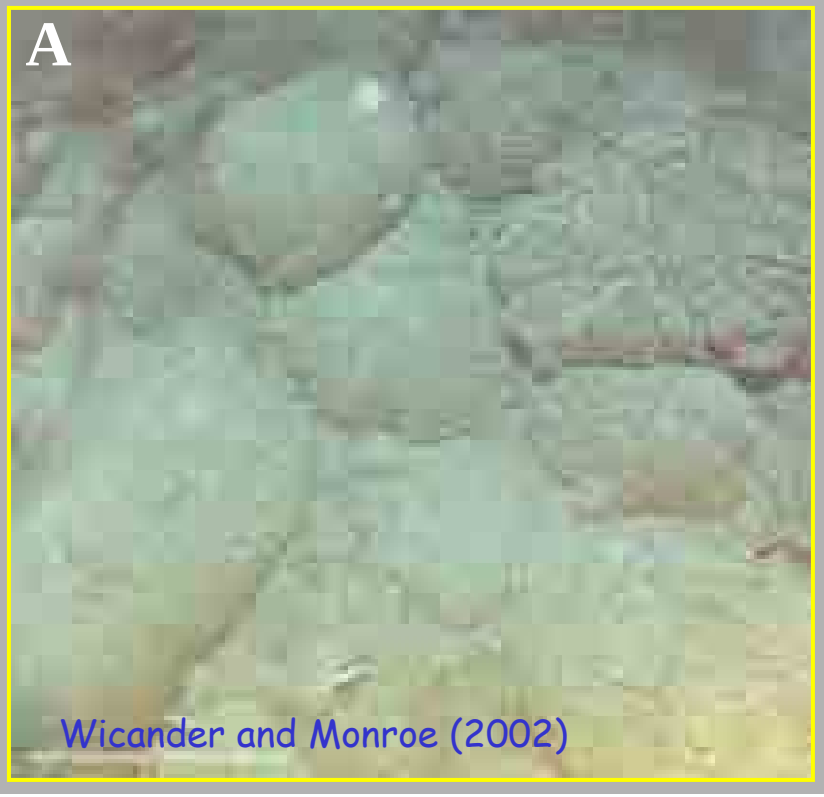
Text: pg 115



Chernicoff and Whitney (2002)

Volcanism - Lava Flows

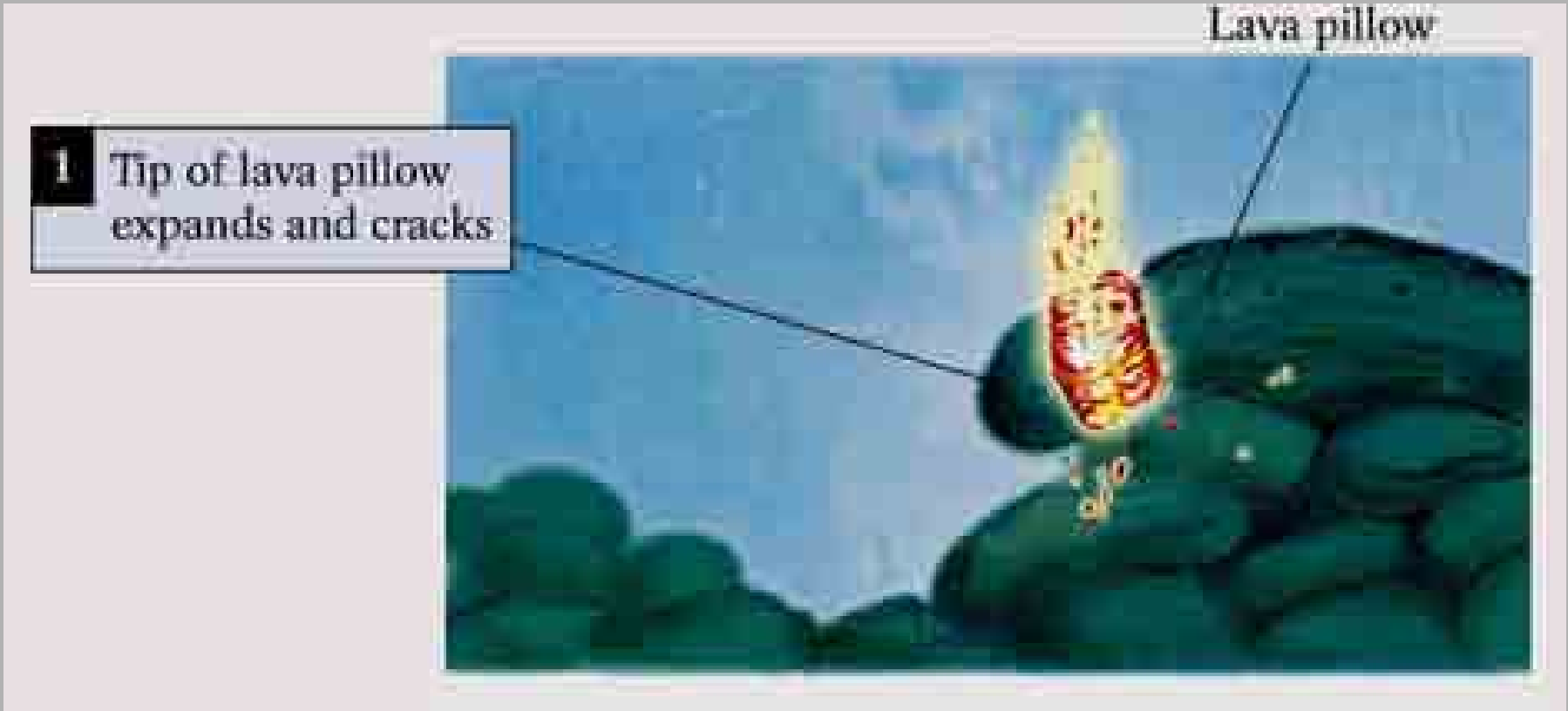
Pillow lava refers to bulbous, pillow shaped masses of basalt formed when lava is rapidly chilled underwater. Pillow lava forms much of modern oceanic crust and is present in slices of ancient oceanic crust shoved on the margins of continents by compressive tectonic forces.



Wicander and Monroe (2002)

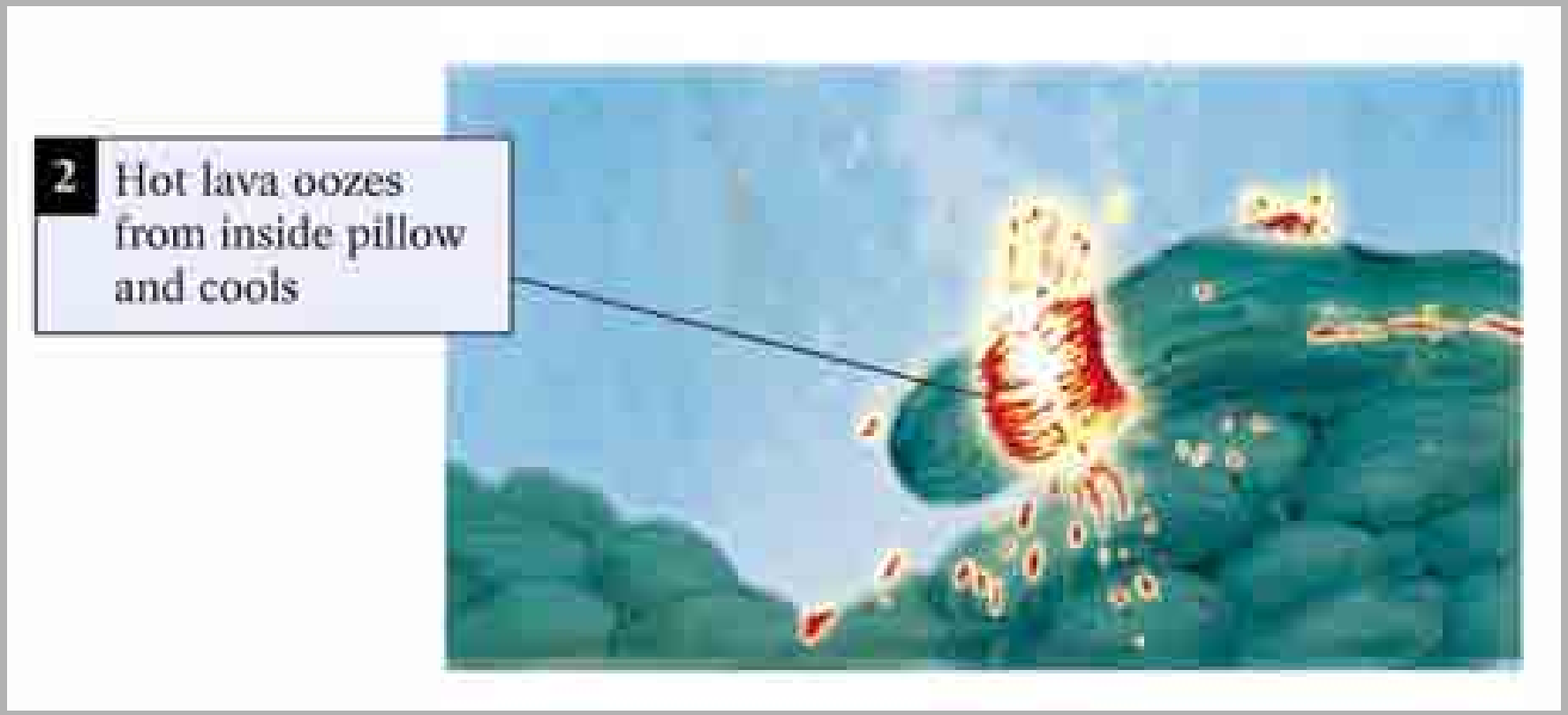
2.7 Ga pillow basalts, Wawa subprovince

Basaltic pillow lavas



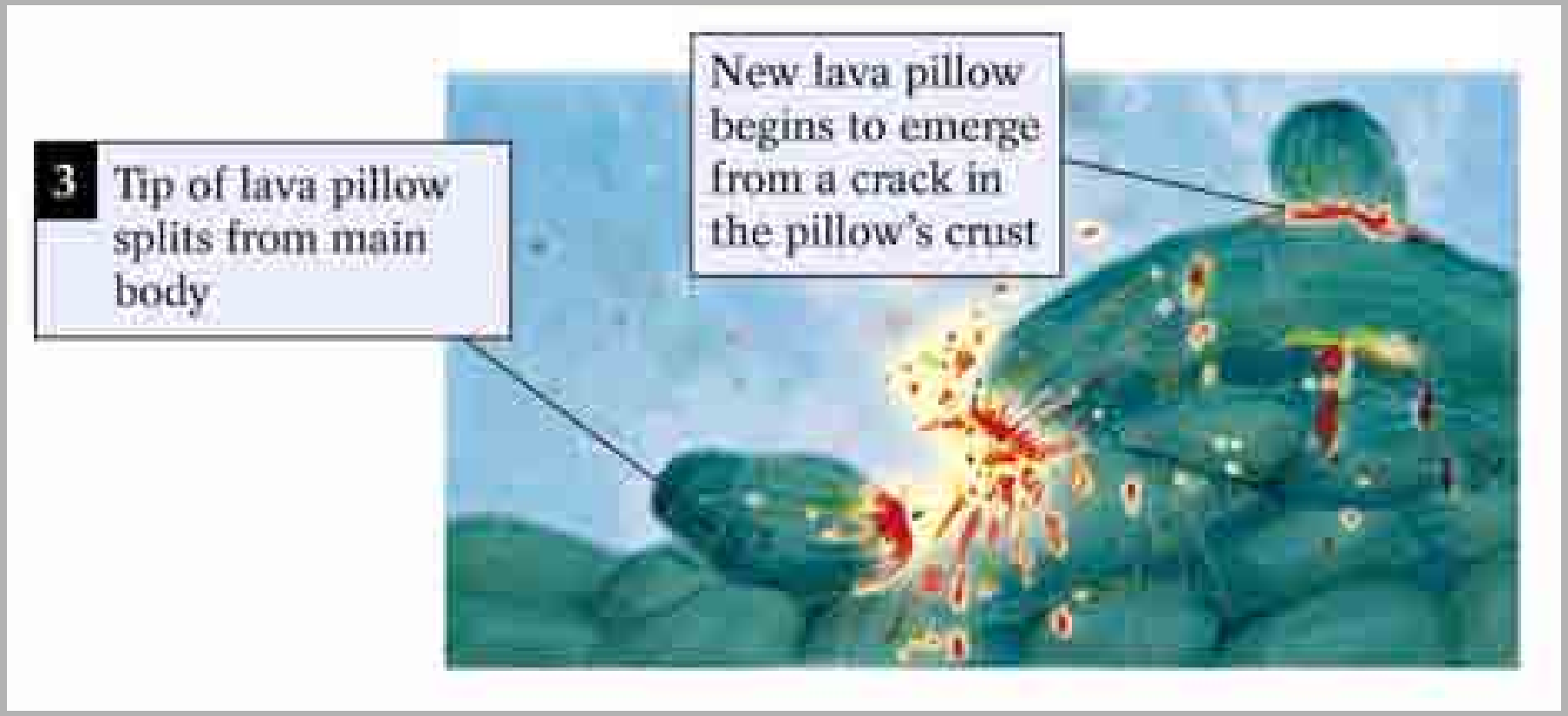
Chernicoff and Whitney (2002)

Basaltic pillow lavas



Chernicoff and Whitney (2002)

Basaltic pillow lavas



Chernicoff and Whitney (2002)

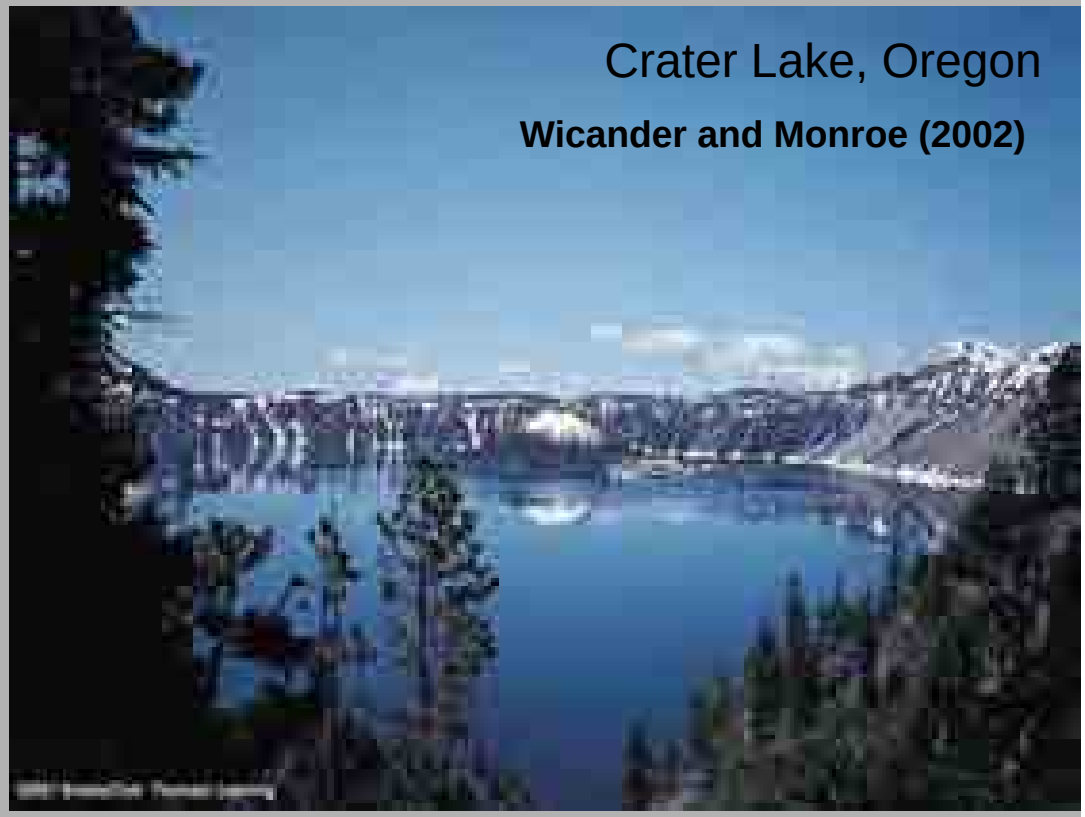
Volcano Terminology

Craters, circular depressions <1 km in diameter, are found at the summit of many volcanoes.

Dukono volcano, Indonesia, Photo courtesy of Bruce Gemmell

Terms…

The summits of some large volcanoes have calderas instead of craters. Calderas are much larger depressions than craters, steep-sided, and often 10s of km in diameter. Crater Lake in Oregon is a water-filled caldera.



Crater Lake, Oregon

Wicander and Monroe (2002)

Types of eruptions

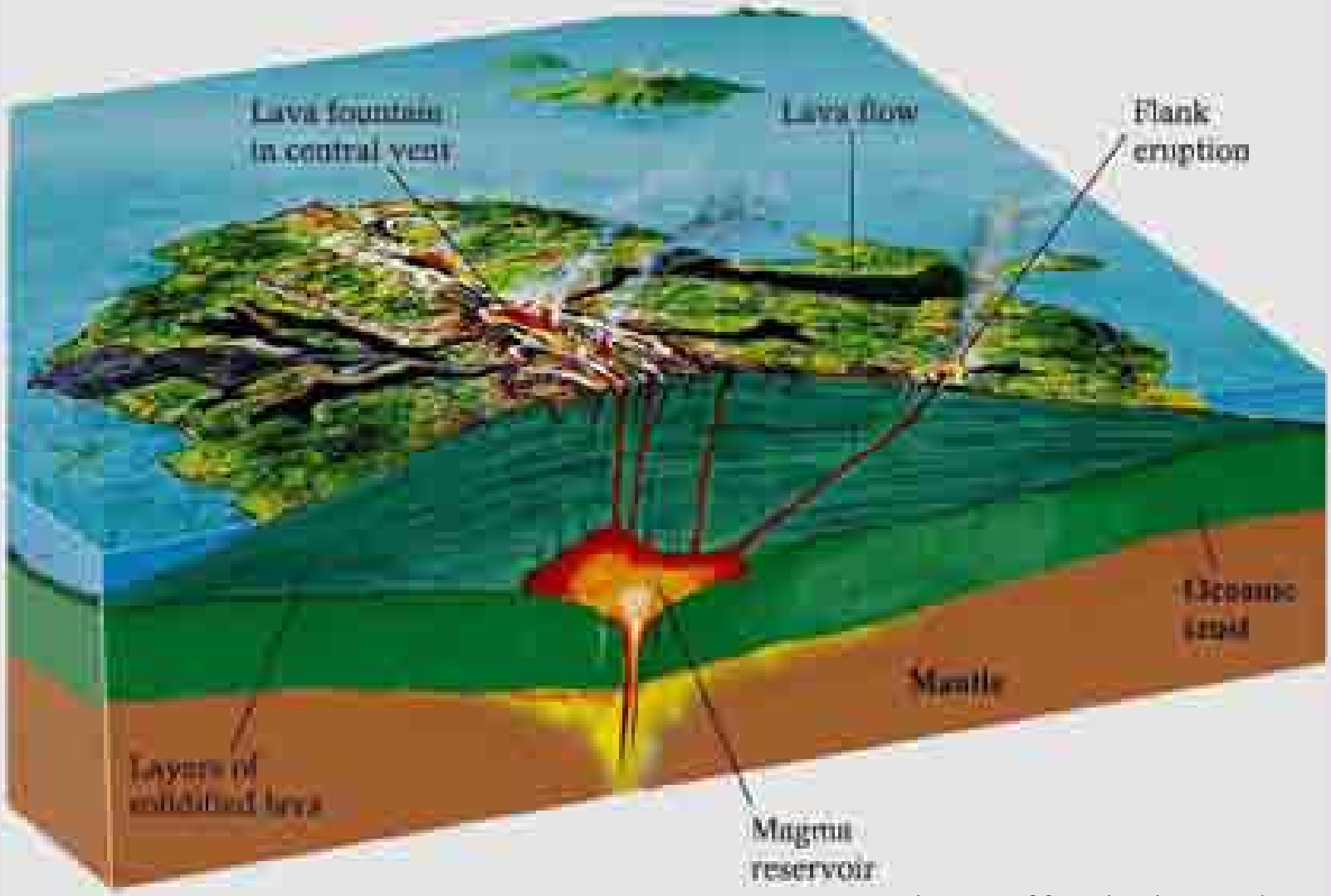
- The different lavas associated with volcanic eruptions determines the shape of the volcanic cone
  - Shield volcanoes – Typically oceanic in origin formed by the gentle outpourings of fluid lavas (e.g. Hawaii and Iceland). The most recent eruptions from Pu'u O'o destroyed 75 homes and covered 10 kms of residential streets. Associated with mantle plumes
  - Stratovolcanoes or Composite volcanoes – typically associated with explosive eruptions resulting in stratified layers of ash, cinders and lavas. Associated with subduction zones. Potentially the most hazardous eruption type

Shield Volcanoes

Shield volcanoes have low, round profiles with gently sloping sides. Formed of low viscosity mafic lava flows, these largest of volcanoes are commonly 50 km or more in diameter. Their eruptions are relatively quiet and non-explosive. The island of Hawaii consists of five large shield volcanoes, including Kilauea and Mauna Loa.

Lassen County, California,
Wicander and Monroe (2002)

Shield volcanoes



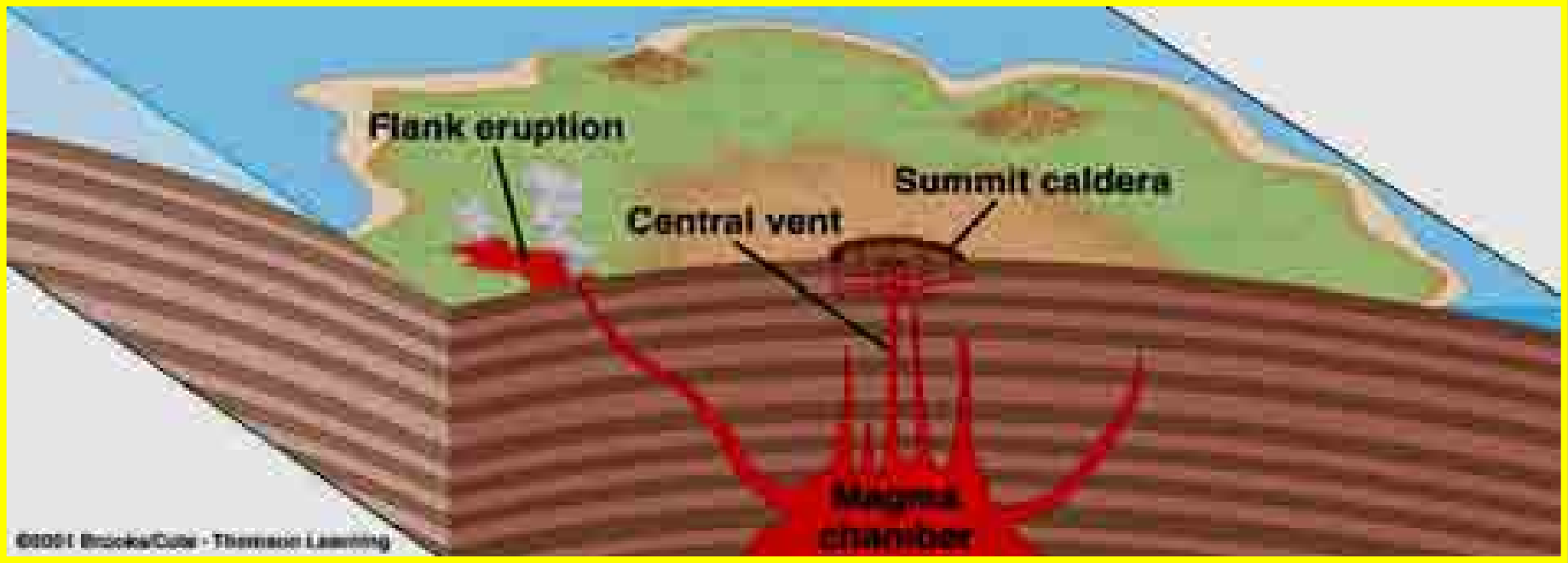
Chernicoff and Whitney (2002)

Shield volcanoes - Mauna Kea

Murck and Skinner (1999)

Shield Volcanoes

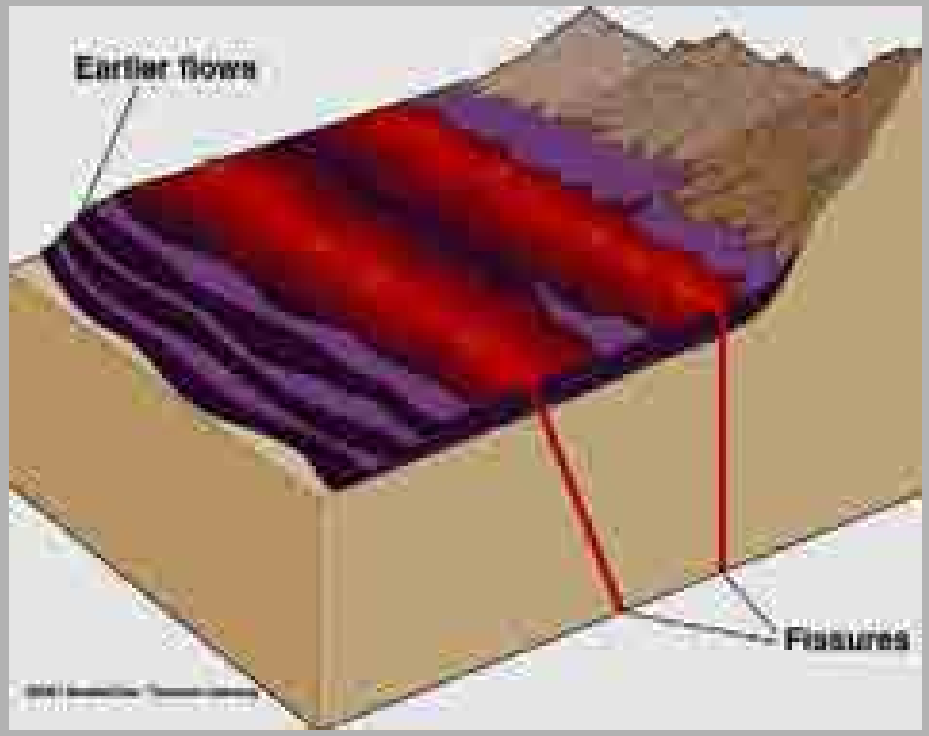
Mauna Loa rises 10.2 km from the sea floor which exceeds Mt Everest (9.1 kmasl)



Wicander and Monroe (2002)

Fissure eruption

Not all eruptions take place at the central vents of volcanoes. Fissure eruptions can produce great quantities of basaltic lava from long cracks or fissures not associated with volcanoes.



Wicander and Monroe (2002)

Fissure eruptions

Northeast rift zone of Mauna Loa, Hawaii, http://hvo.wr.usgs.gov

Eruptive fissure on southeast rim of Kilauea caldera, Hawaii
http://hvo.wr.usgs.gov

Explosive eruptions

- High silica, high viscosity magmas tend to erupt explosively
- The explosive release of gas blasts fragments of material in all directions
- These fragments are called pyroclastic material

  Pyro = fire *klastos* = broken
- Pyroclastic material is deposited as tuffs and agglomerates

Text page 115

Pyroclastic Material

Pyroclastic material is ejected from volcanoes. Ejected particles < 2mm in diameter are referred to as ash. Lapilli are 2 to 64 mm and bombs >64 mm in diameter.

Wicander and Monroe (2002)

Pyroclastic deposits

Pyroclastic Material - Pele’s hair

Thin strands of volcanic glass drawn out from molten lava have long been called Pele's hair, named for Pele, the Hawaiian goddess of volcanoes. A single strand, with a diameter of less than 0.5 mm, may be as long as 2 m. The strands are formed by the stretching or blowing-out of molten basaltic glass from lava, usually from lava fountains, lava cascades, and vigorous lava flows.

Photograph by D.W. Peterson, http://volcanoes.usgs.gov

Pyroclastic Material - Pele’s tears

Small bits of molten lava in fountains can cool quickly and solidify into glass particles shaped like spheres or tear drops called Pele's tears, named after Pele, the Hawaiian goddess of volcanoes. They are jet black in color and are often found on one end of a strand of Pele's hair.

Photograph by J .D. Griggs , http://volcanoes.usgs.gov

Composite Volcanoes

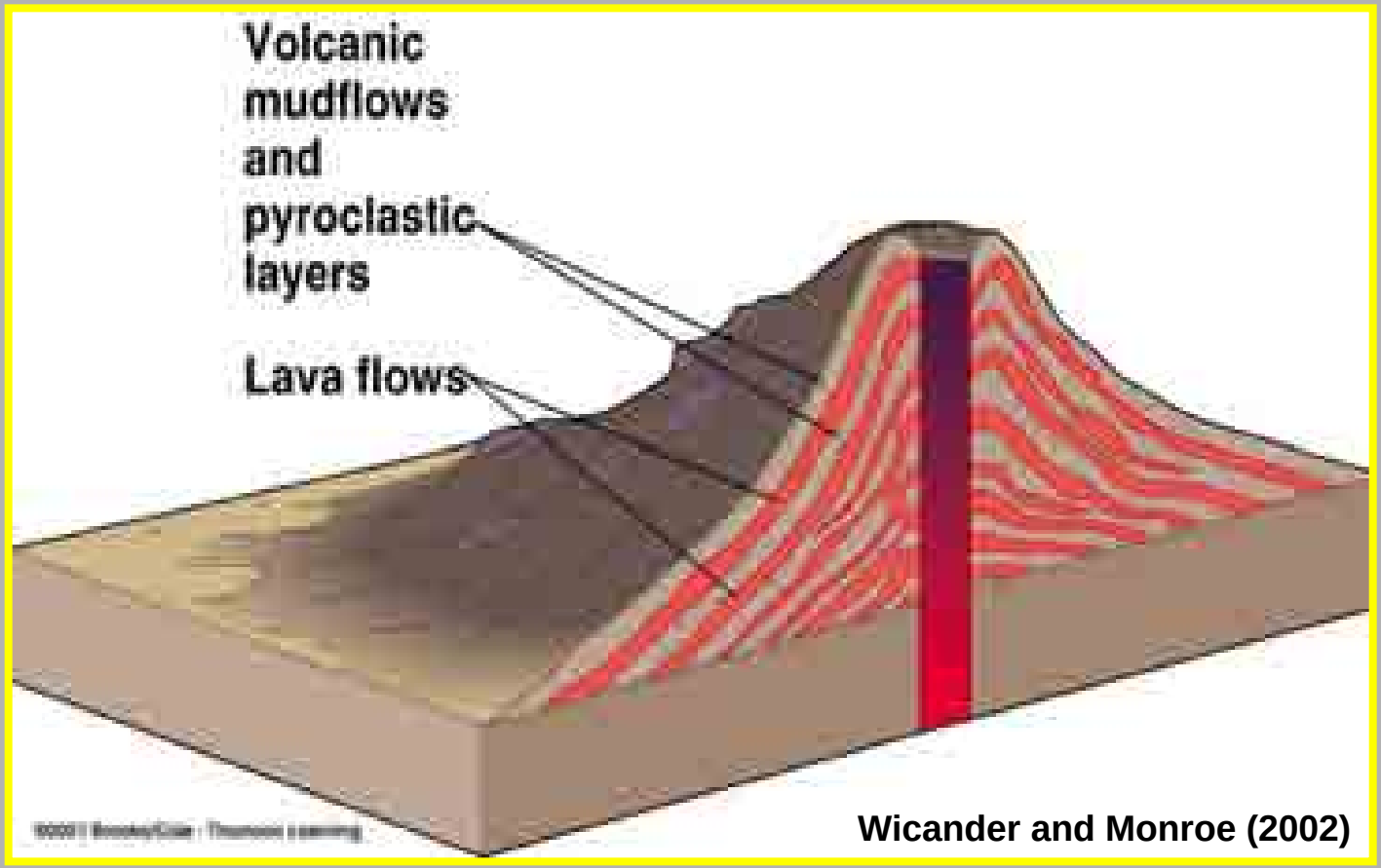
Composite volcanoes (stratovolcanoes) consist of both lava flows and pyroclastic layers. Both materials are of intermediate/andesitic composition.

Text pg 116, Figure 4.17 & 4.18

Gamkonora volcano, Indonesia
Photo courtesy of Bruce Gemmell

Composite Volcanoes

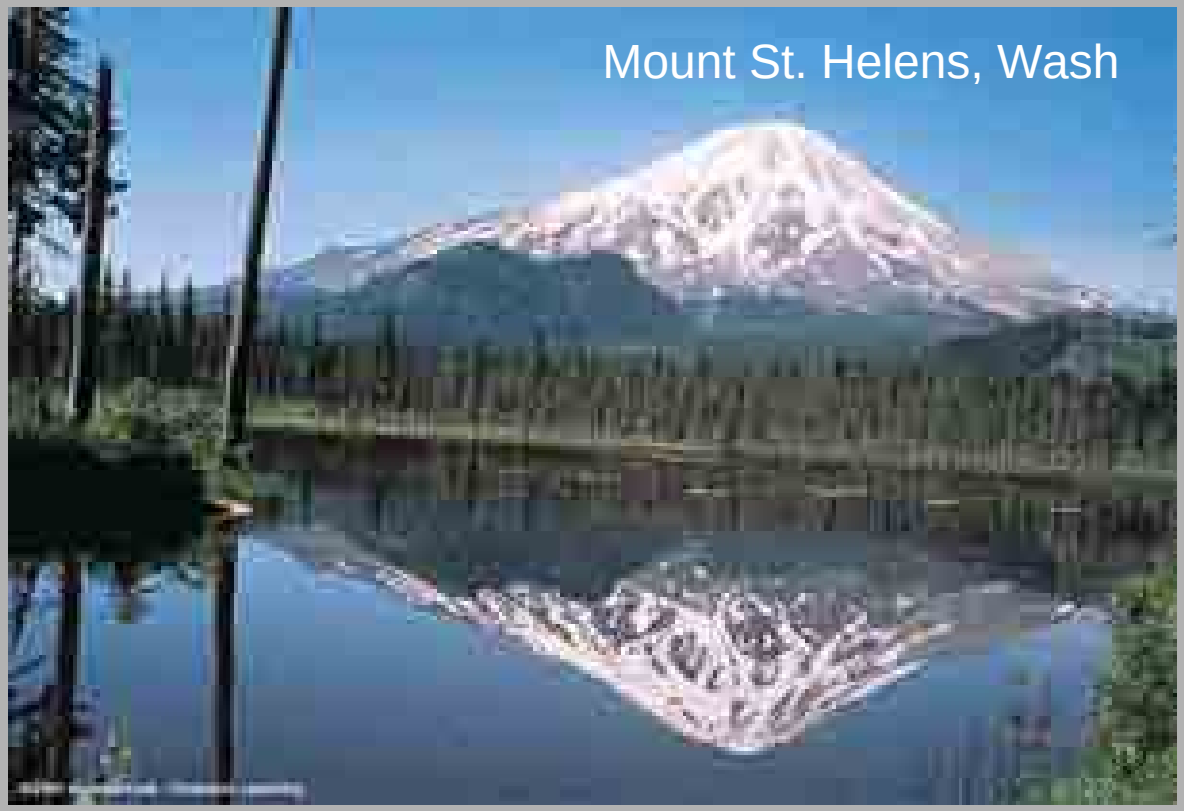
Due to the more viscous lava, these volcanoes have steep sides, concave slopes, and can erupt explosively.



Wicander and Monroe (2002)

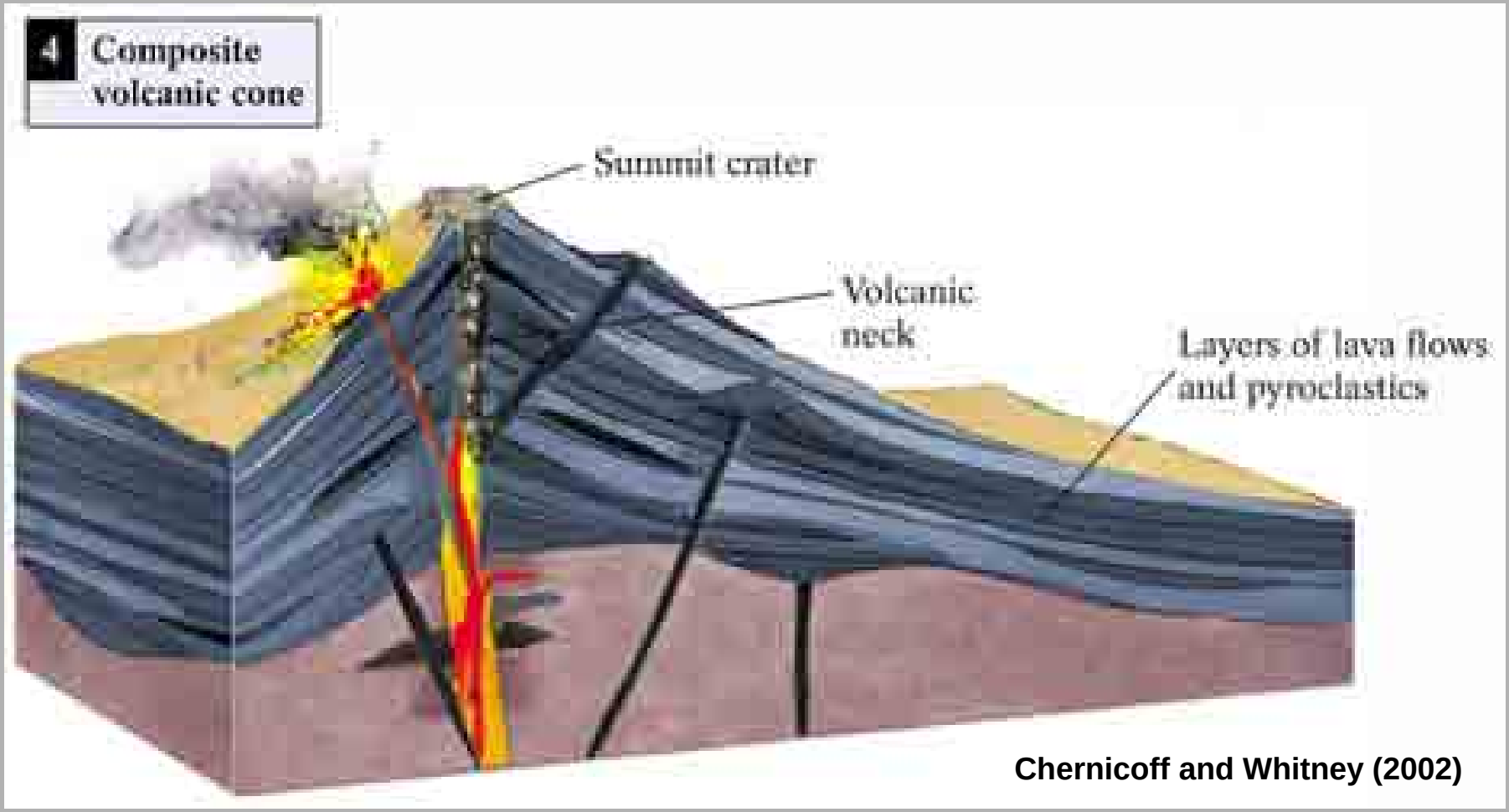
Composite Volcanoes

They commonly are 5-20 km in diameter, associated with convergent plate boundaries, and form picturesque mountains like those of the Cascade range in the NW U.S.



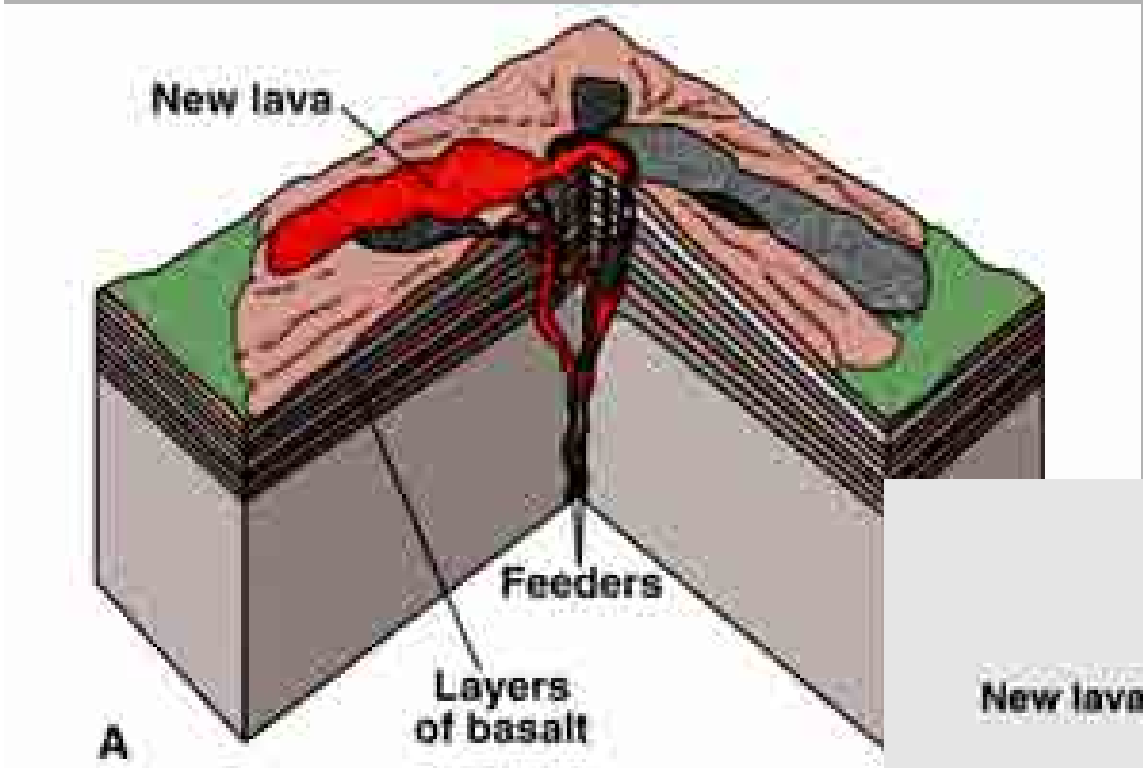
Wicander and Monroe (2002)

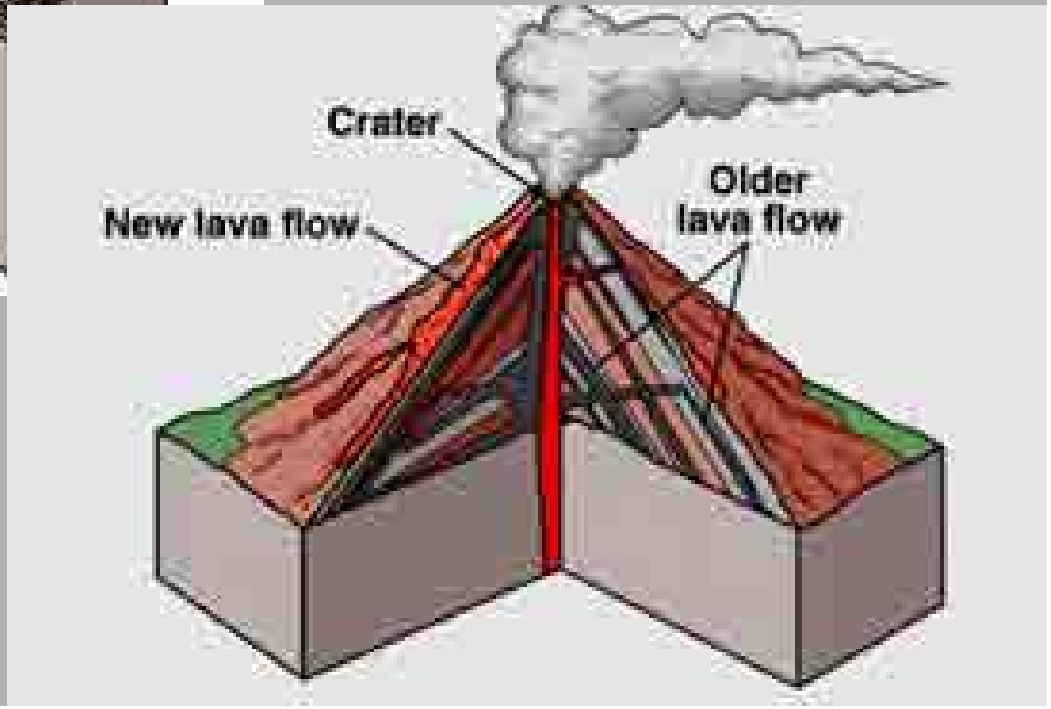
Composite cones



Chernicoff and Whitney (2002)

Shield vs. composite



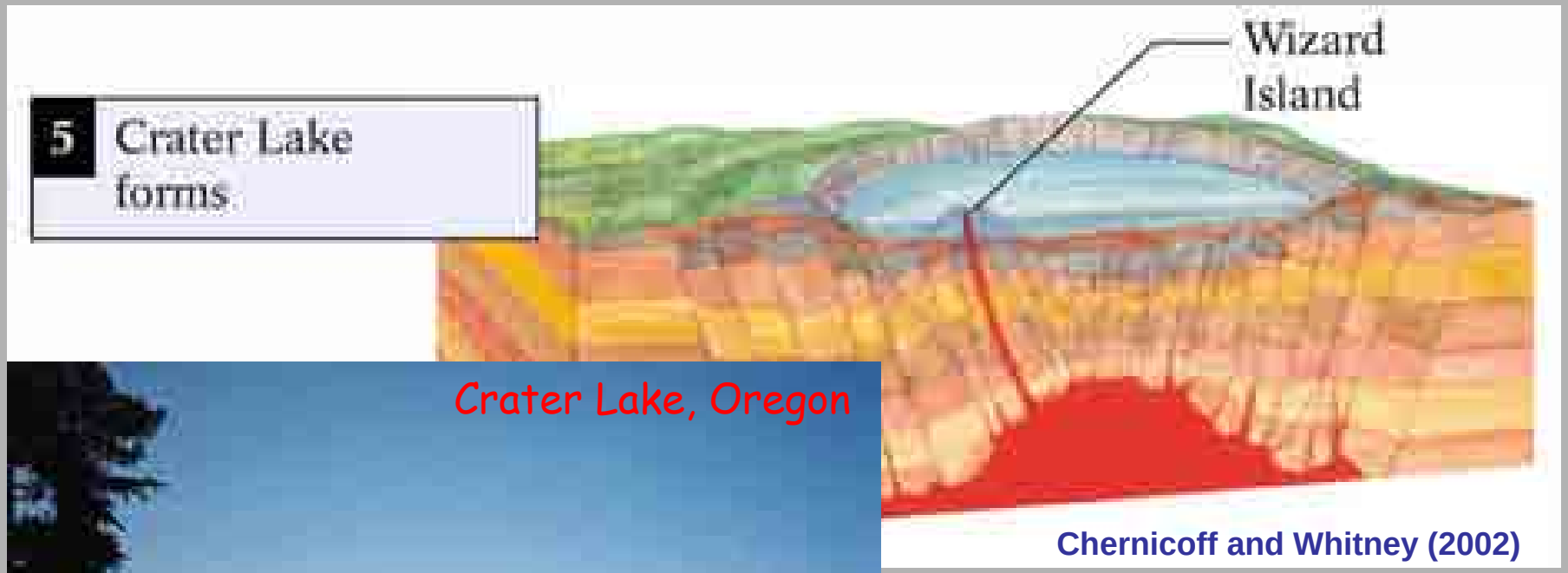


Plummer et al. (2001)

Other features:

- Crater lake
- Cinder cones
- Splatter cones
- Lava domes
- Hot springs and geysers
- Mud volcanoes
- Fumaroles

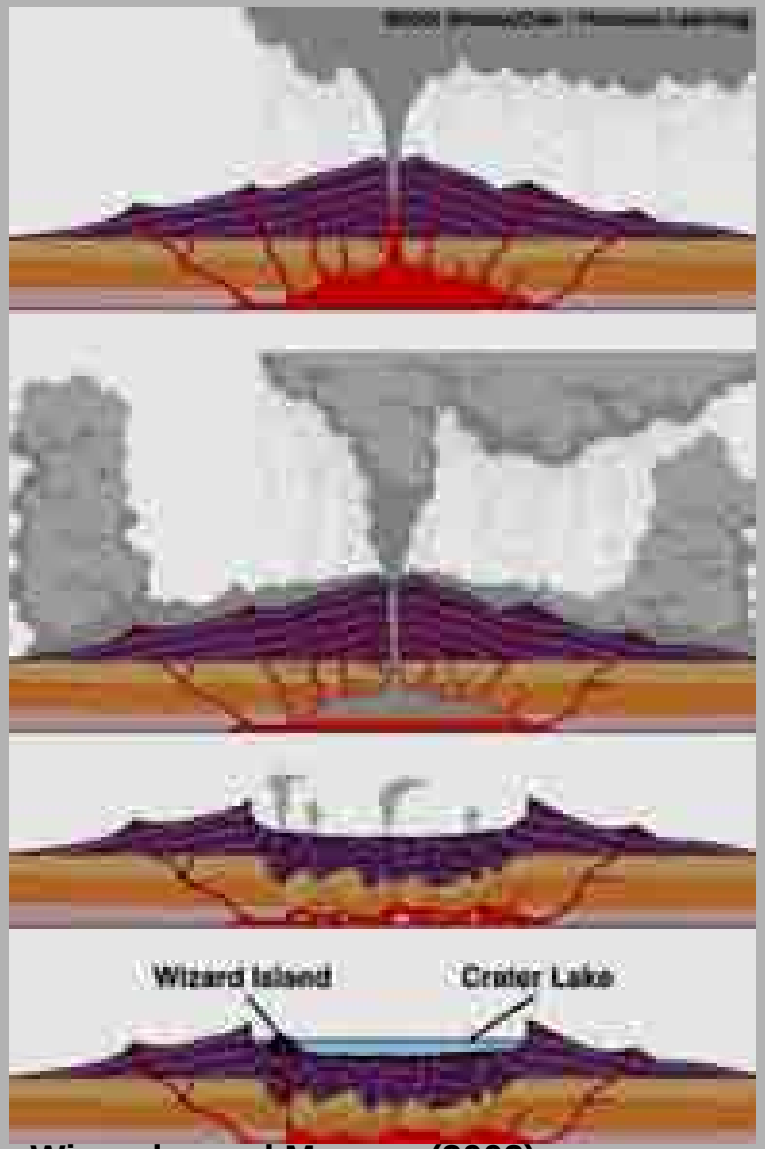
Mount Mazama: crater lake



Chernicoff and Whitney (2002)

Wicander and Monroe (2002)

Formation of a Crater lake:



Wicander and Monroe (2002)

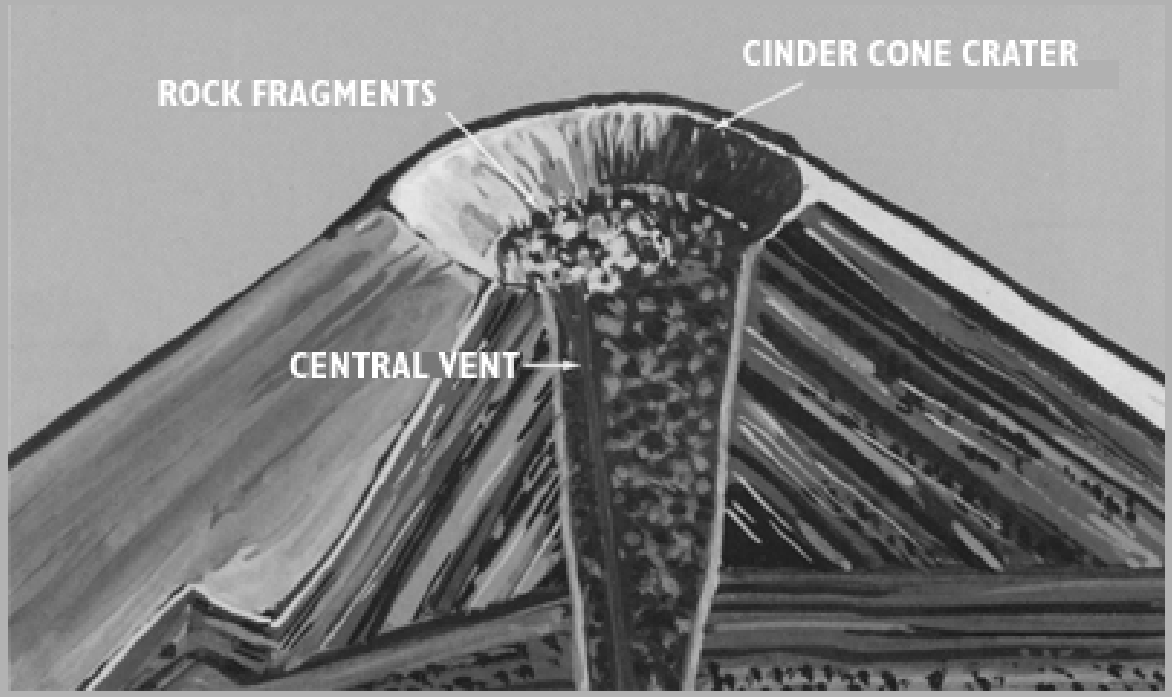
- Pyroclastic eruption empties magma chamber beneath volcano.
- Summit collapses forming caldera.
- Small volcano forms in caldera and caldera fills with water.

Text: pg 122, Fig. 4.28

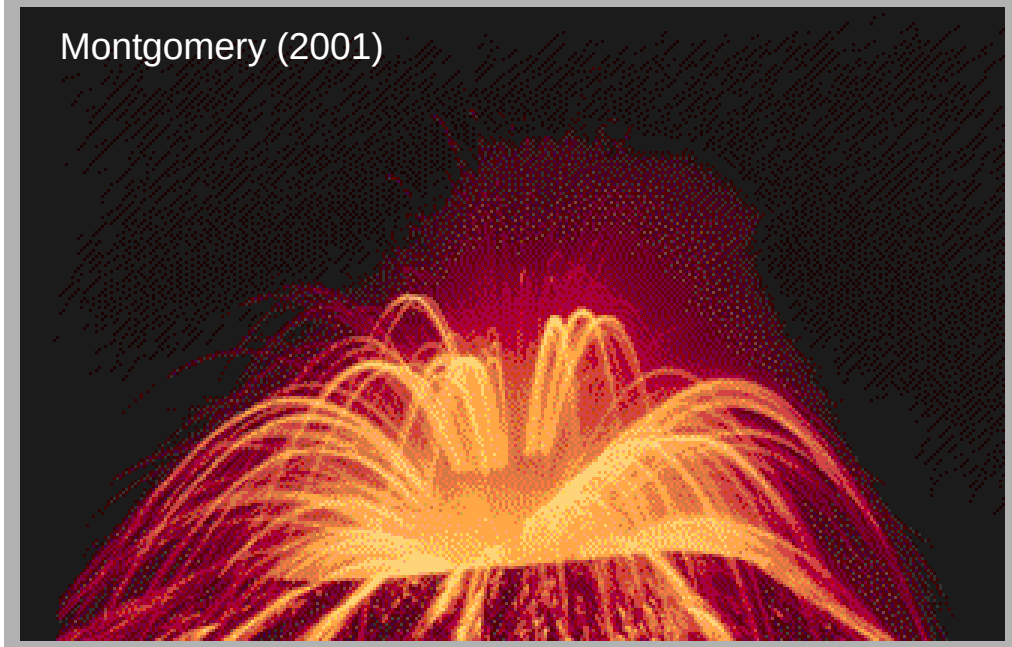
Cinder Cones

- Cinder cones are formed of pyroclastic material
- They are relatively steep-sided, < 1 km in diameter, and usually <400 meters high
- They often form on the flanks of larger volcanoes, are associated with basaltic volcanism, and are common in the southern Rocky Mountain states, such as New Mexico and Arizona (below)

Wicander and Monroe (2002)



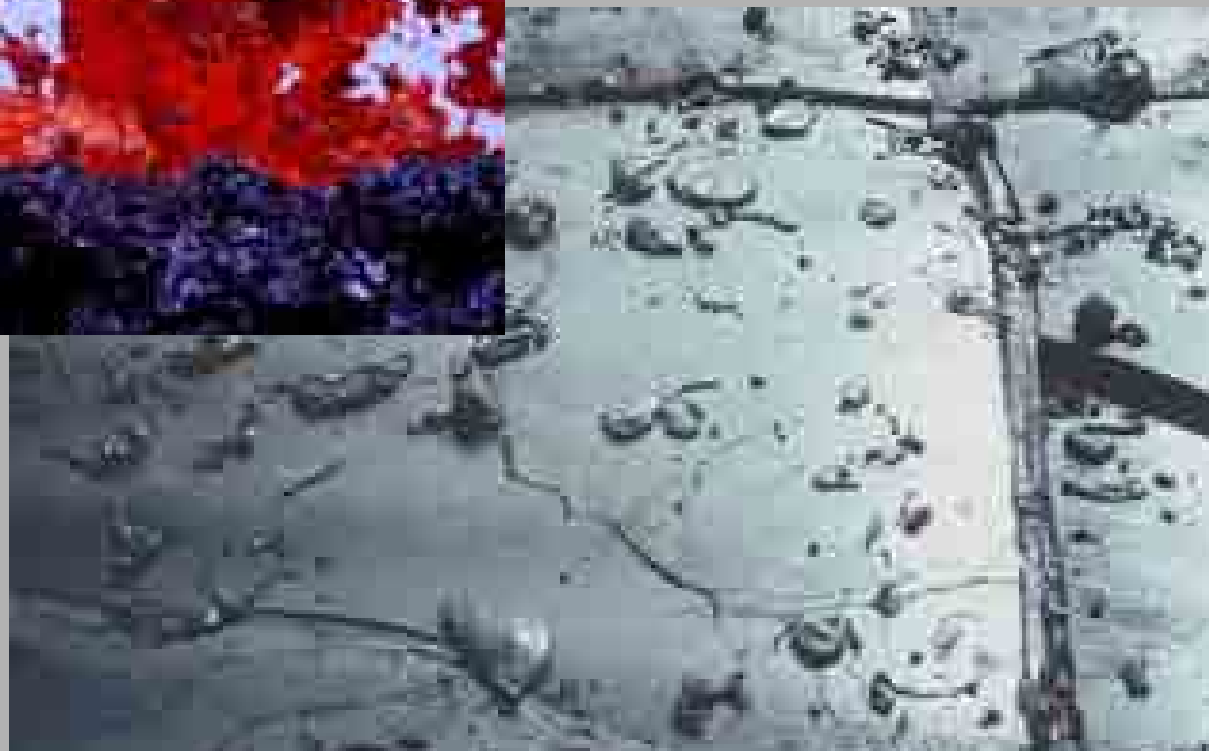
Cinder cones



- Paricutin Volcano, Mexico, 1943-1952
- Started as fuming crack reaching height of 400m

Spatter cones

•Clumps of molten lava (spatter) hurled above the rim of a spatter cone have already started to cool and develop a thin black skin on their surface. Width of the image is about 3 m.
http://volcanoes.usgs.gov



•Close view of cooled, solidified spatter fragments hurled from an active littoral cone on the south shoreline of Kilauea Volcano. The impact of the molten spatter hitting the ground flattened the fragments into roughly circular disks.
http://volcanoes.usgs.gov

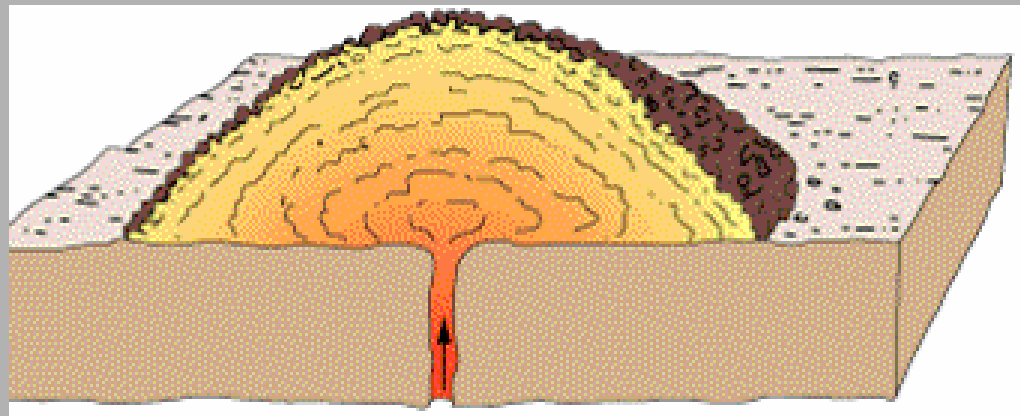
Spatter cones

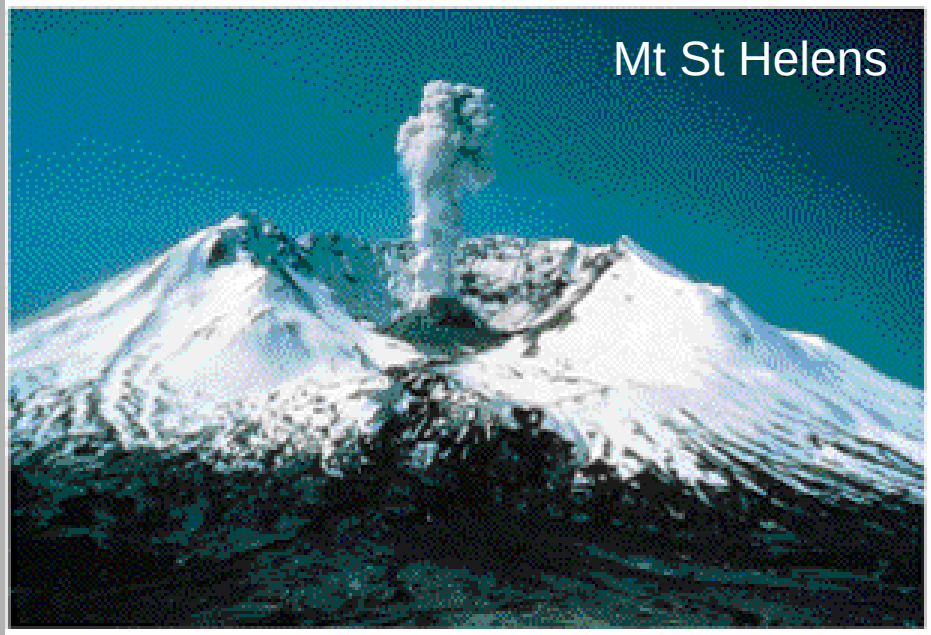
Lava fountain from the main vent of Pu`u `O`o adds new tephra to its towering spatter and cinder cone. In 1986, the cone was about 255 m tall. The summit was built higher than the main vent (about 86 m higher) as tephra from dozens of tall fountains between 1983 and 1986 was blown by the persistent trade winds toward the southeast.

http://volcanoes.usgs.gov

Lava Domes

Lava domes are bulbous dome-shaped features formed of the most viscous (felsic) lava. They are often associated with composite volcanoes where they can form plugs atop vents in the crater and contribute to extremely explosive eruptions.





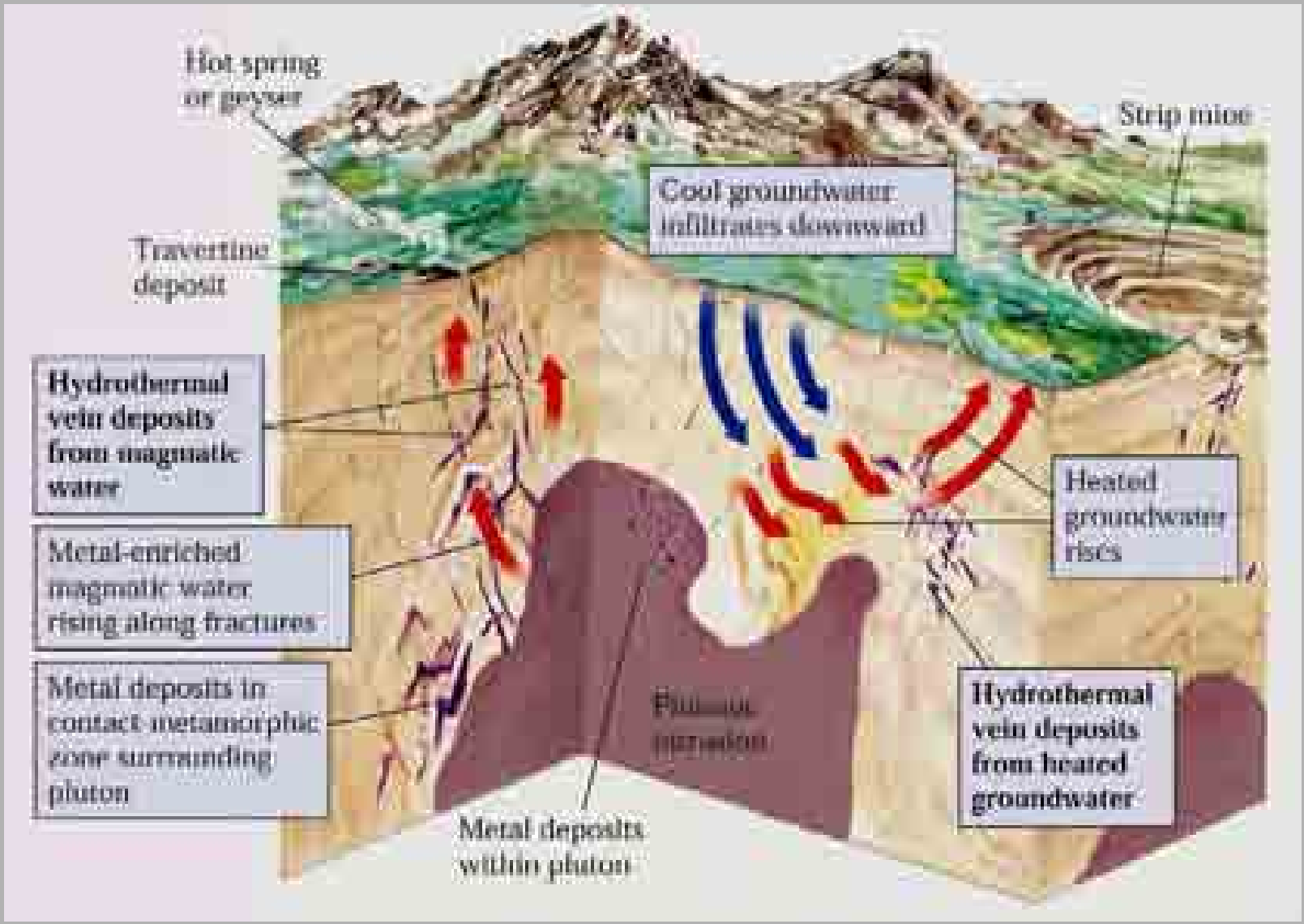
Montgomery (2001)

Lava Domes

- Mt. Lassen in northern California is the world's largest lava dome
- In 1902, eruption of a lava dome volcano on the Caribbean island of Martinique destroyed the city of St. Pierre, killing its 28,000 residents in a 2-3 minute period

Wicander and Monroe (2002)

Hot springs and geysers



Chernicoff and Whitney (2002)

Geysers

Lady Knox geyser, New Zealand

Hot springs

Champagne Pools, Wai O Tapu, New Zealand

Mud volcanoes

- A mud volcano is a small volcano-shaped cone of mud and clay, usually less than 1-2 m tall
- Built by a mixture of hot water and fine sediment (mud and clay) that either (1) pours gently from a vent in the ground like a fluid lava flow; or (2) is ejected into the air like a lava fountain by escaping volcanic gas and boiling water.

Photograph by S.R. Brantley
http://volcanoes.usgs.gov

Mud volcano in the Norris Geyser Basin, Yellowstone National Park, Wyoming. The mud volcano is about 40 cm tall.

Boiling mud

Boiling mud, Wai-O-Tapu, New Zealand

Fumaroles

Volcanic Fumarole, White Island, New Zealand

http://volcanoes.usgs.gov

Active Volcanoes

Stromboli, Italy

Aeolian Islands,
Italy

38.79 N, 15.21 E,
summit elevation
926 m
stratovolcano

Active Volcanoes

Mt. Etna, Italy

Rated #2 in the greatest amount of lava produced in the world

37.73 N, 15.00 E,
summit elevation 3350 m
Shield volcano