Volcanism and Earth's Systems

- Early Earth's (pre-Cambrian)
  - *Atmosphere*
    - created from *volcanic gases*
  - *Hydrosphere*
    - partially from condensation of *volcanic water vapor*
  - *Biosphere* (today)
    - positively and negatively influenced by volcanism
      - Lava flows and ash "weather" producing fertile soils
      - Violent eruptions can destroy all life in their paths
      - Large amounts of ash and volcanic gases in atmosphere
        - triggers rapid climate changes
        - contributes to ***mass extinctions***

Living with Volcanoes

- Mythology, religion and volcanoes
  - Hawaii - Pele
  - Iceland - Loki
- Growth of volcanic islands (Hawaii)
- Geothermal energy
  - Natural steam harnessed as clean energy resource
- Climatic effects
  - Global cooling
  - Resulting crop failures and famines
- Volcanic catastrophes
  - Mt. St. Helens, Pompeii, Krakatoa, Tambora, Crater Lake

Volcanoes and Volcanism

- Volcanic rocks & processes
  - Ejecta (lavas, pyroclastics, gases), volcaniclastics (lahars, sands, muds)
  - Other features: earthquakes, geothermal systems
- Types of volcanoes
  - Basic types: central vent, fissure, caldera . . .
  - Controls on types: magma composition, T, flux
  - Tectonic distribution and controls
- Volcanoes and people: hazards, resources (geothermal, minerals, water, soil), climate

Volcanic Eruptions

- *Lava* is produced
  - when magma *flows on Earth's surface*
- Explosive eruptions produce
  - rapidly cooled rock fragments called *pyroclastics*
    - Size range from
      - dust (*ash*)
      - to boulders (*blocks and volcanic bombs*)
- Lava flows and pyroclasts pile up to build *volcanoes*

Fig. 4.1-A, pg. 76

Fig. 4.2-B, pg. 76

Eruptive Violence and Physical Characteristics of Lava

- Eruption violence controlled by:
  - *Dissolved **gases*** in magma
    - water vapor
    - carbon dioxide
    - sulfur dioxide, etc.
  - Ease/difficulty of **gases** escaping to atmosphere
    - Wide/Narrow vents
- ***Viscosity***- a ***fluid's resistance to flow***
  - *Silica content*
    - **Higher silica %** produce **higher viscosities** (**thicker** magma)
  - Lava *temperature*
    - **Cooler lavas** have **higher viscosities**
  - Amount of *dissolved gases*
    - The **more dissolved gases**, the *more fluid* the lava

Extrusive Rocks and Gases

- Scientific Investigation of Volcanism
  - Observed rocks, gases and events from eruptions
    - compared to other lavas infers past activity
    - compare chemistry and changes

- Rock Composition
  - *Rhyolite* - high silica; *light* color
  - *Basalt* - low silica; ***dark*** color
  - *Andesite* - intermediate silica and *color*

Extrusive Textures

- Texture - appearance of rock grains wrt/
  - size
  - shape
  - and arrangement
- *Glassy* - glass without mineral crystals
  - ***Obsidian***
- *Fine-grained* - small crystals
  - ***Basalt***
- ***Porphyritic*** -
  - larger crystals mixed with much finer crystals or glass
  - ***Andesite***

Figs. 4.9-A, -B, -C, pg. 85

Extrusive Textures

- ***Vesicular/Frothy***
  - trapped gas bubbles
  - "sponge" appearance
    - *Vesicular basalt*
    - *Pumice*

- ***Fragmental***
  - pieces blown out by explosive eruptions
    - *Dust and ash (<2 mm)*
    - *Cinders (2-64 mm)*
    - *Blocks and bombs (>64 mm)*

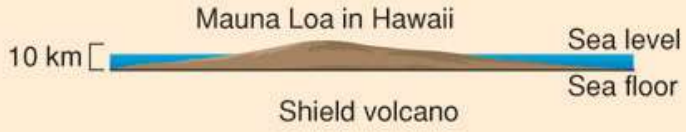
Volcanic Landforms

- *Vent*
  - opening through which lava erupts
- *Crater*
  - basin-like depression at the vent
  - usually on volcanoes' summit
- ***Caldera***
  - volcanic depression larger than the original crater
  - indicates past explosive event

Types of Volcanoes

- ***Strato***volcanoes
  - Cinder cones
- ***Shield*** Volcanoes

Table 4.2 Comparison of the Three Types of Volcanoes

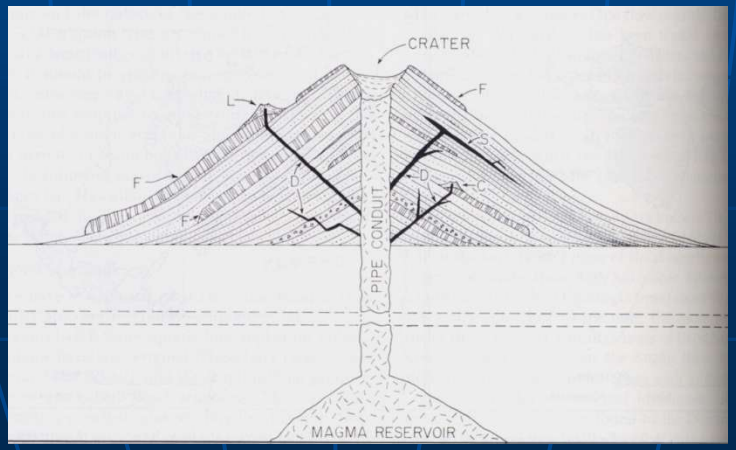
Profile of Volcano	Description	Composition
 Shield volcano	**Shield Volcano** Gentle slopes—between 2 and 10 degrees. The Hawaiian example rises 10 km from the sea floor.	Basalt. Layers of solidified lava flows.
< 300 meters  Cinder cone	**Cinder Cone** Steep slopes—33 degrees. Smallest of the 3 types.	Pyroclastic fragments of any composition. Basalt is most common.
Typically 1000 to 4000 meters  Composite volcano	**Composite Volcano** Slopes less than 33 degrees. Considerably larger than cinder cones	Layers of pyroclastic fragments and lava flows. Mostly andesite.

Types of Volcanoes

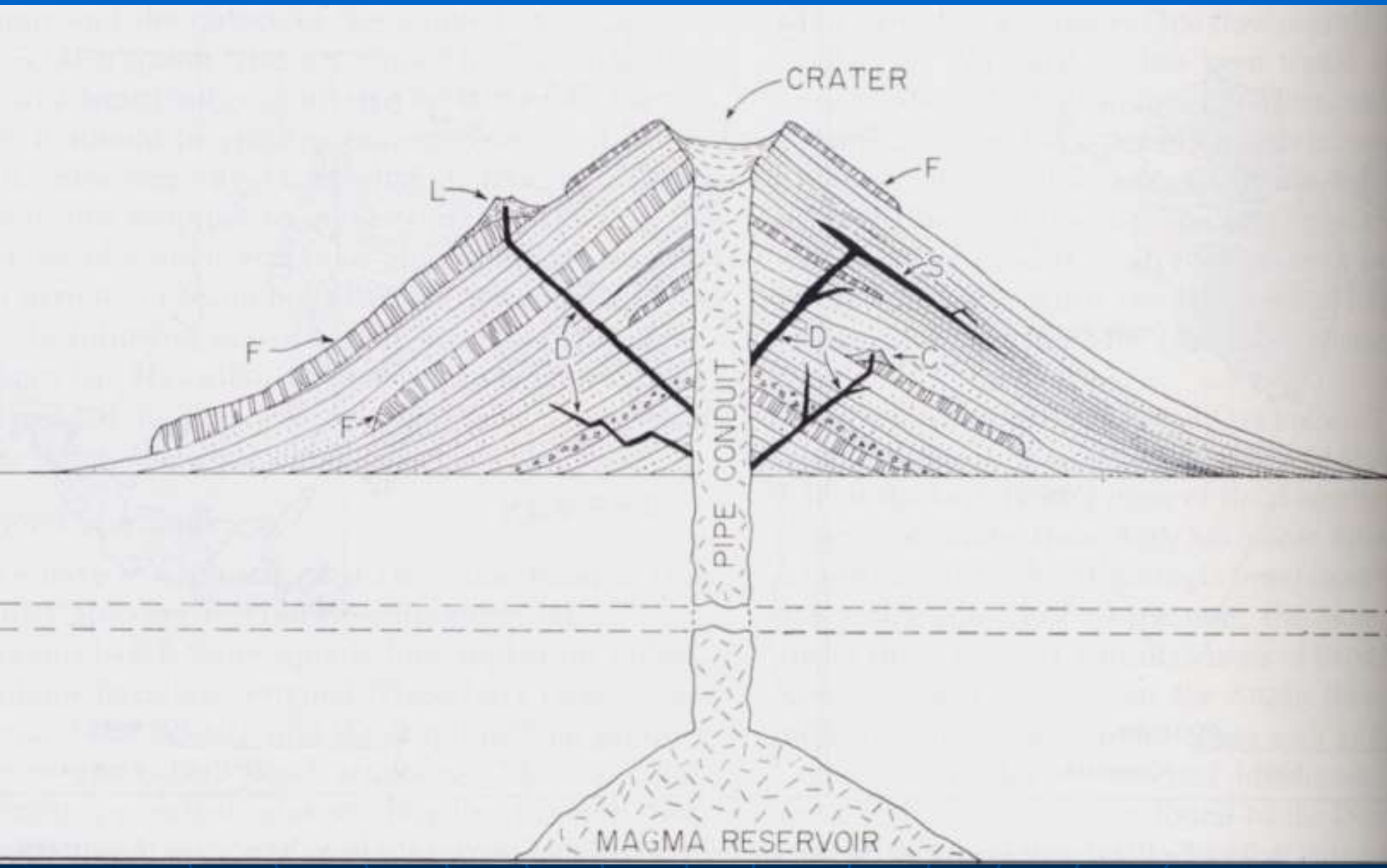
- Shield Volcanoes
- Cinder Cones
- Composite Volcanoes
- Volcanic Domes

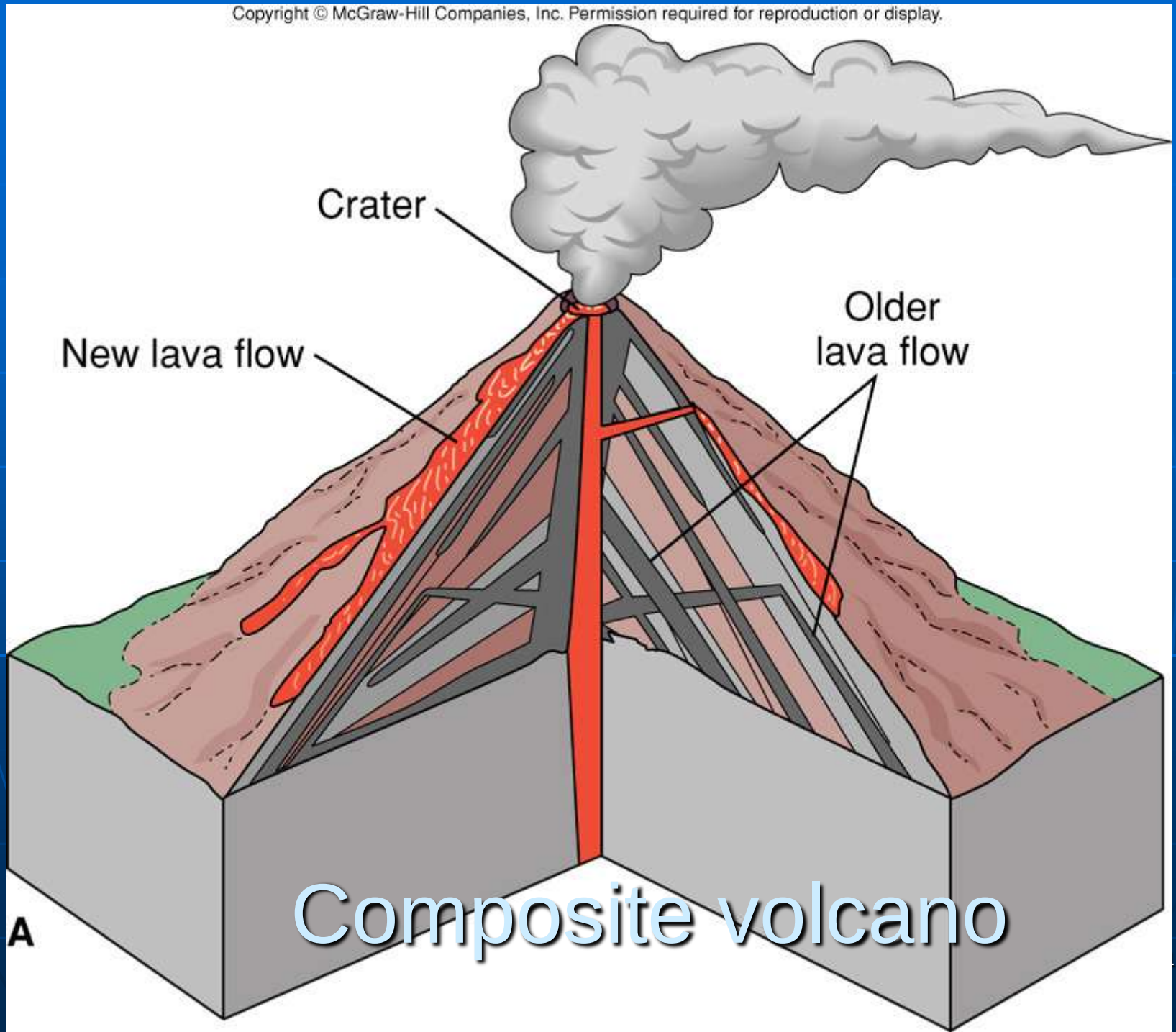
*Strato*volcanoes

- Have ***thick, felsic* lavas** (rhyolite, andesites)
  - with a high viscosity (thick & gummy)
- Lava doesn't travel far
  - combines with tephra to build **tall cones**
- Summit crater is the main vent
- Lots of "gas" in the magma
- Often termed a **"composite"** volcano
  - ash, lava mixture
- ***Glowing avalanches*** (clouds of white hot gas and ash) are common - ***"lahars"***

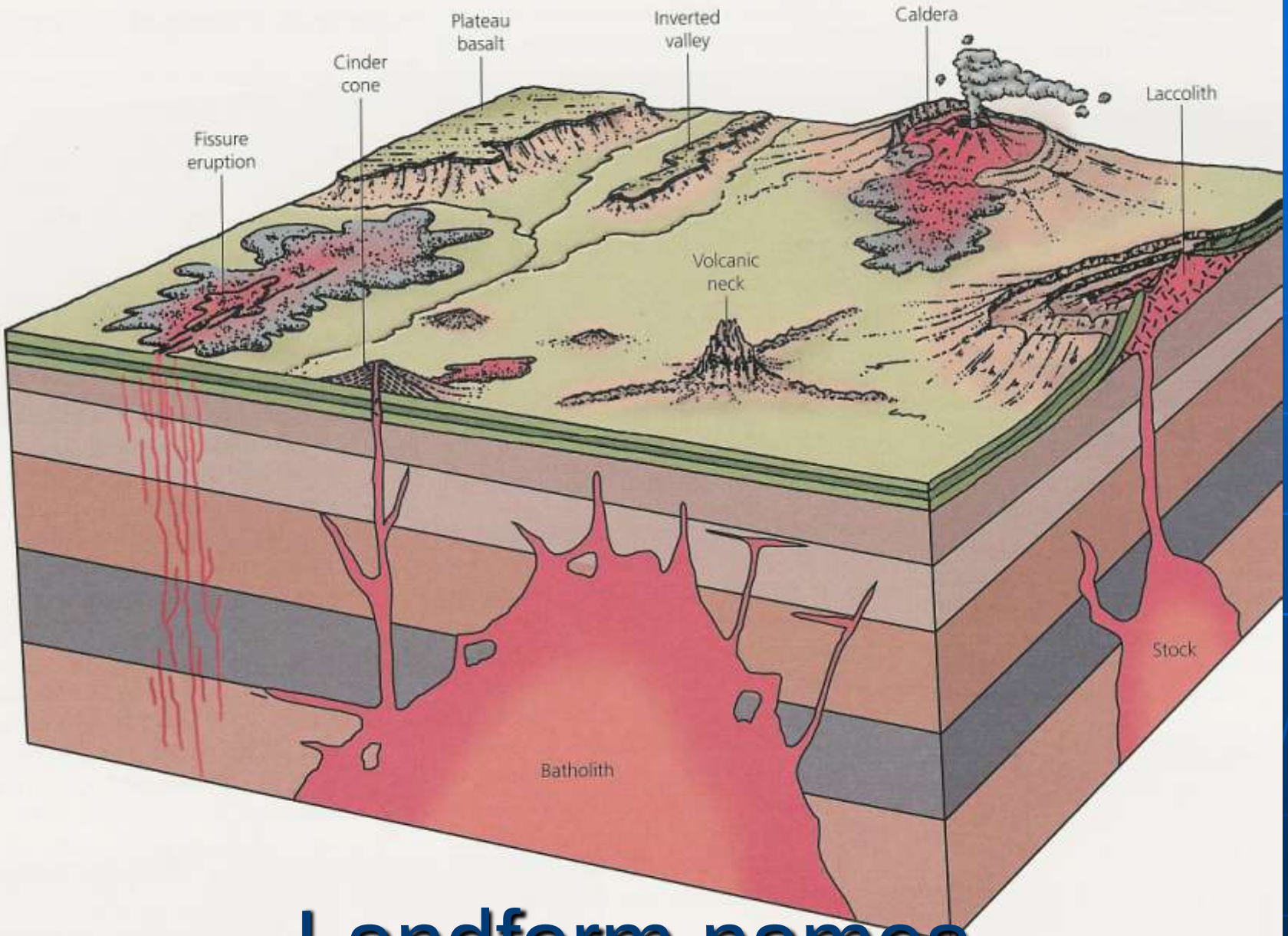


*Strato*volcanoes





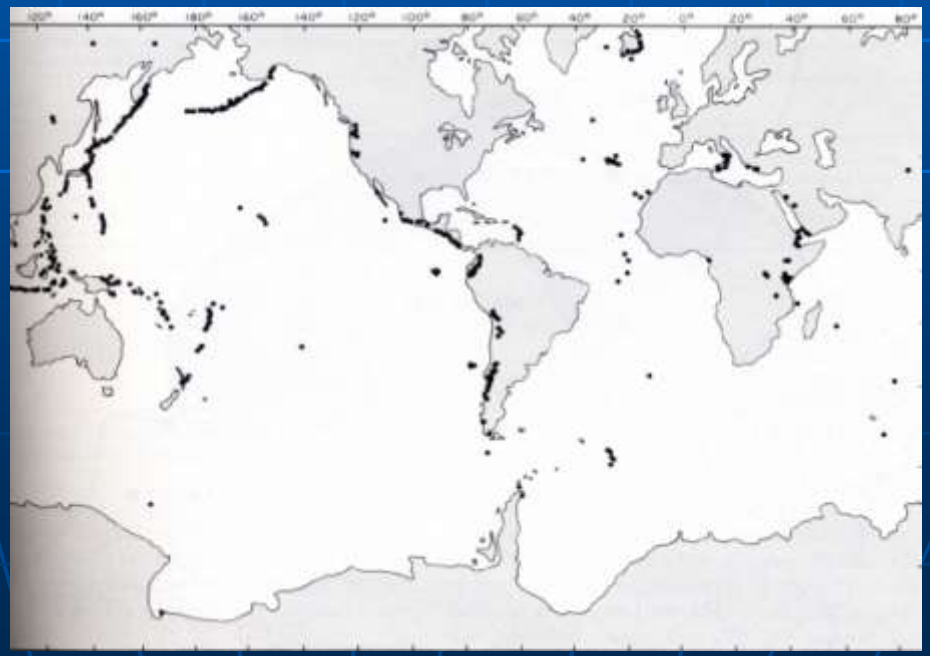
Composite volcano



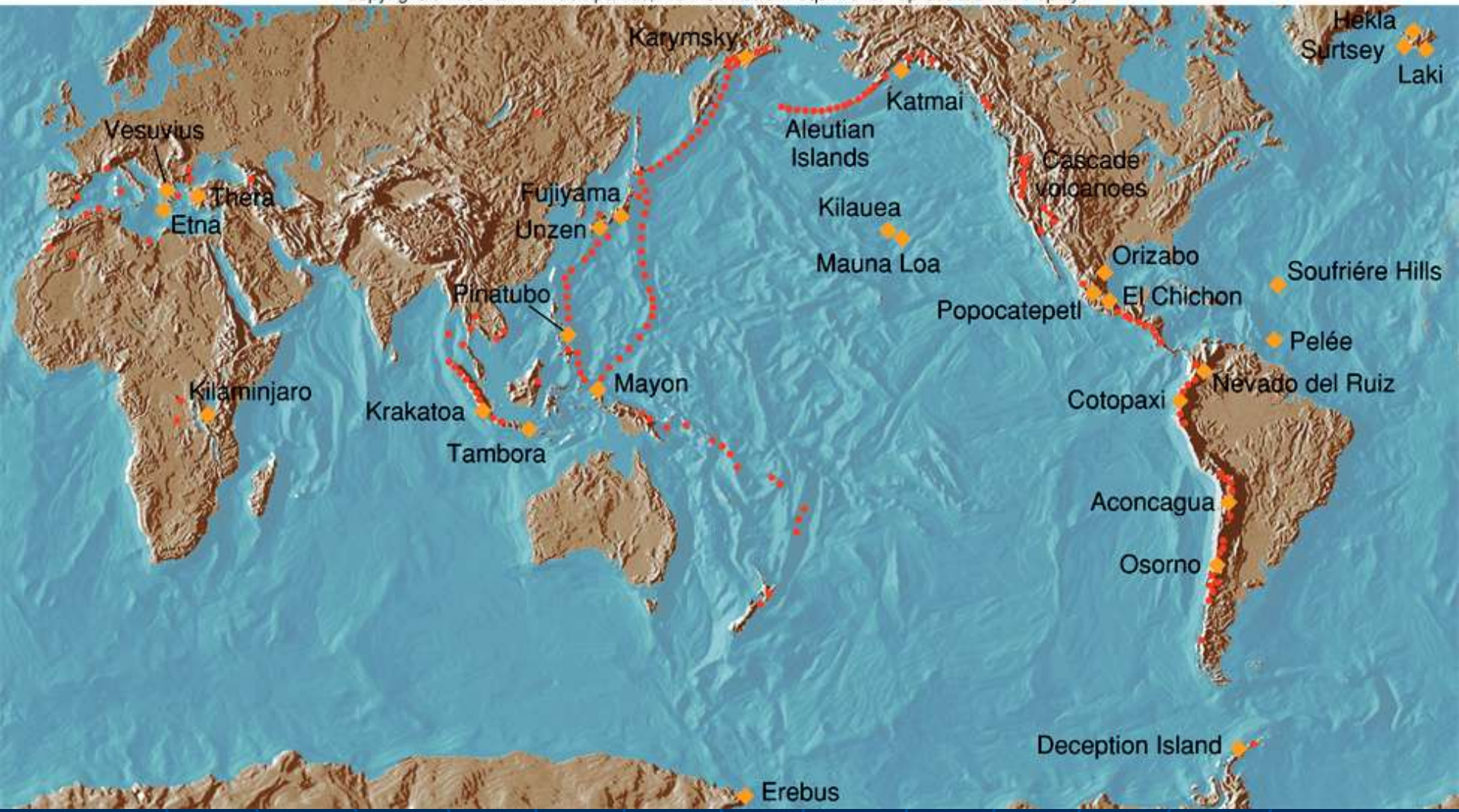
Landform names

*Strato*volcanoes

- Often ***catastrophic explosions*** that create ***calderas*** (Krakatoa, Mt. St. Helens, Crater Lake)
- Most found in the circum-Pacific belt
  - Pacific "Ring of Fire"



Ring of fire



Cascades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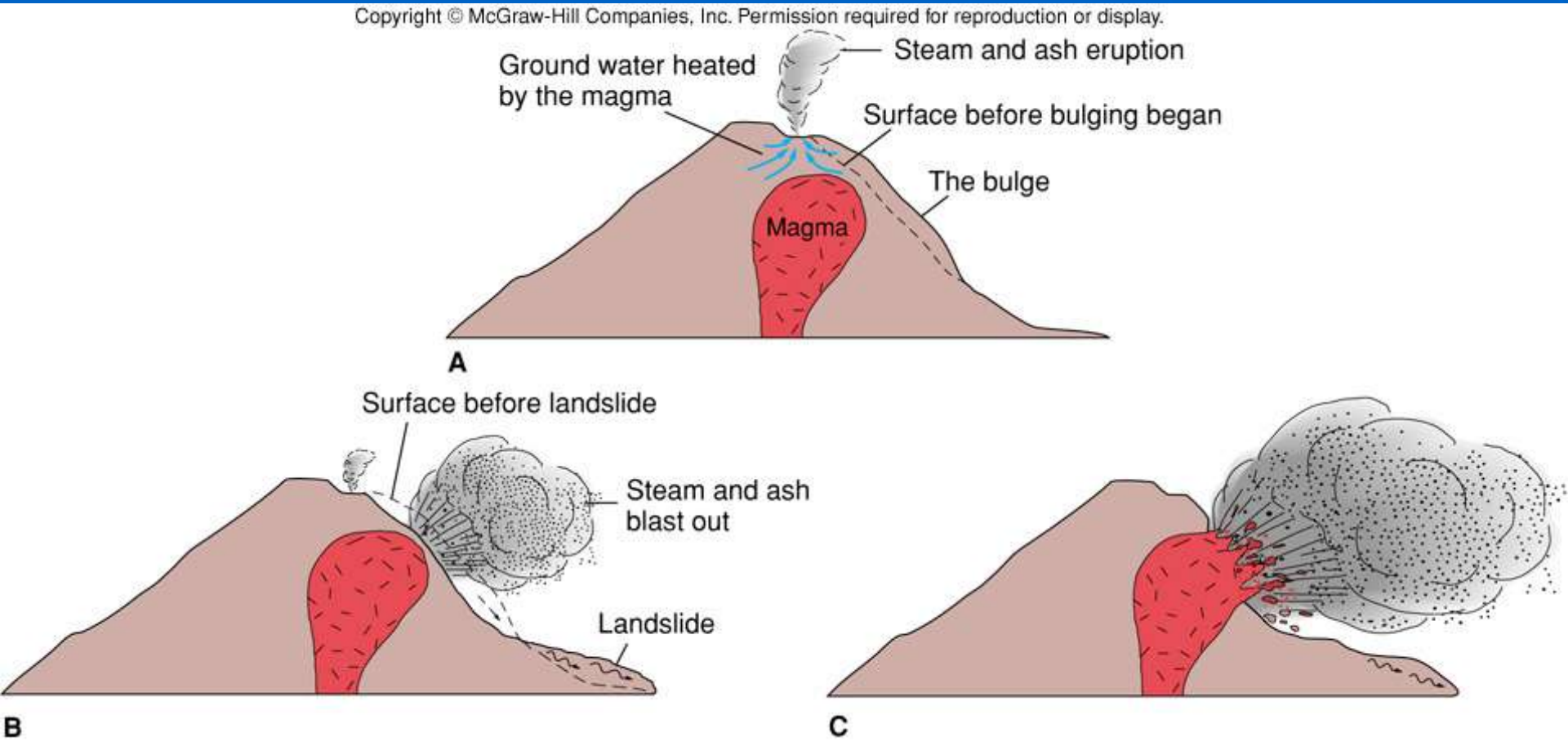
North
Mt. Garibaldi
BRITISH COLUMBIA
Vancouver
Mt. Baker
Glacier Peak
Seattle
WASHINGTON
Mount Rainier
Olympia
Tacoma
Mount
St. Helens
Mount Adams
Portland
Mount Hood
Willamette
Valley
Mount Jefferson
Eugene
Three Sisters
OREGON
Mt. Thielsen
Crater Lake
Medford
Mount McLoughlin
Mount Shasta
Redding
CALIFORNIA
Lassen Peak
Sacramento
Valley

Mt. St. Helens


Copyright © McGraw-Hill Companies, Inc. Permission required for reproduction or display.
Ground water heated by the magma
Steam and ash eruption
Surface before bulging began
The bulge
Magma
A
Surface before landslide
Steam and ash blast out
Landslide
B
C

Dome in Mt. St. Helens crater

Photo by C. C. Plummer

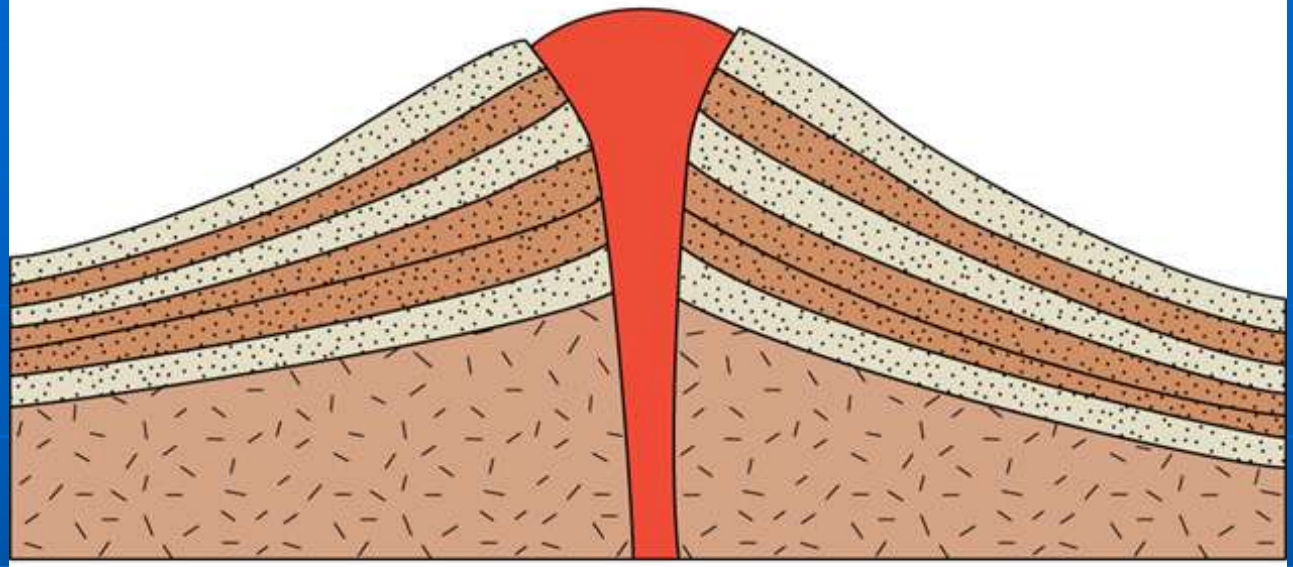
St. Pierre, Martinique 1902

Photo by Underwood & Underwood, courtesy Library of Congress

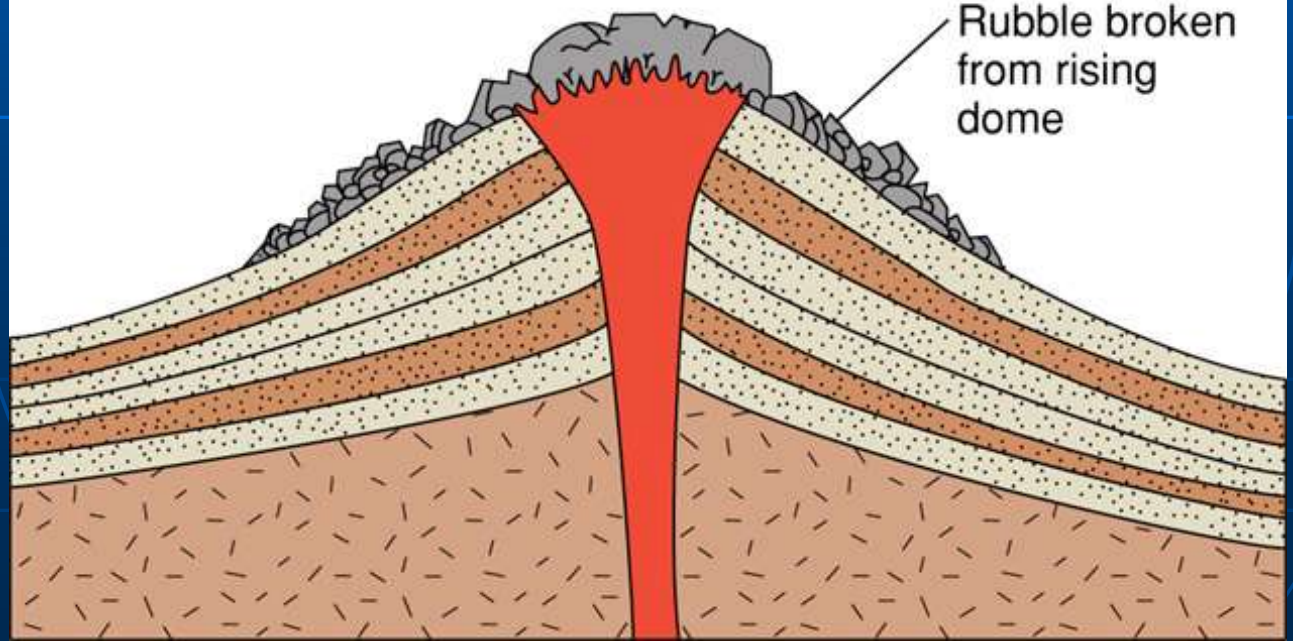
Kamchatka crater, caldera

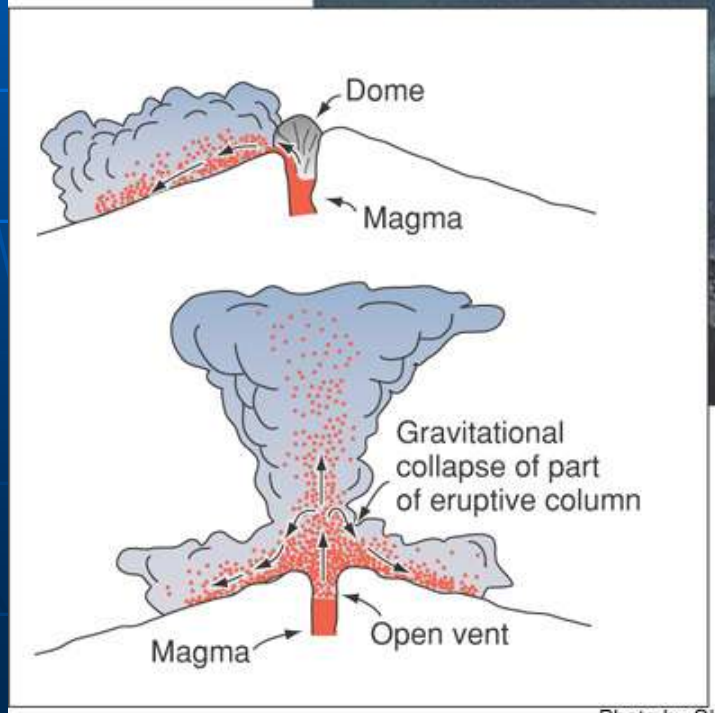
Photo by C. C. Plummer

Viscous lava welling up into a crater



Volcanic dome

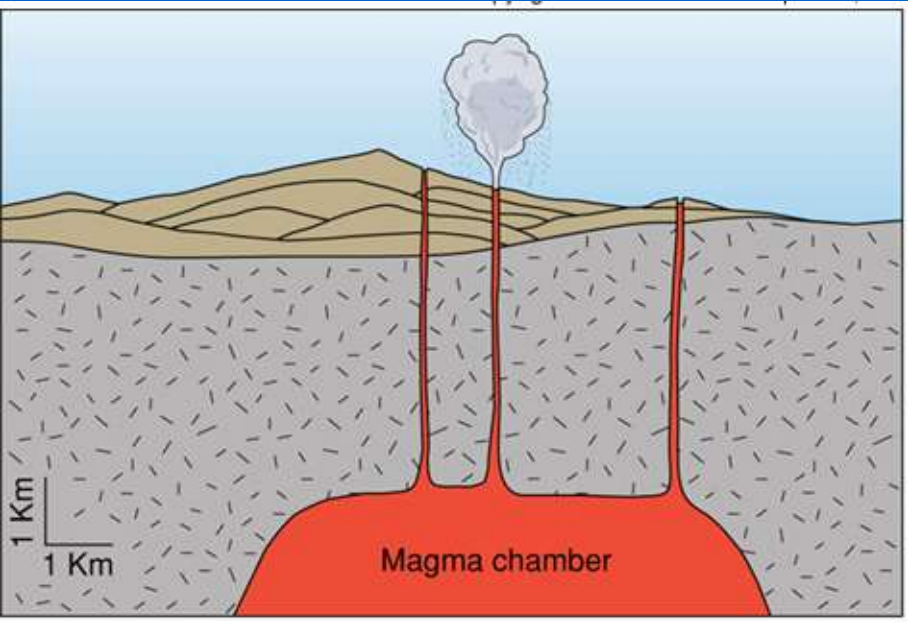




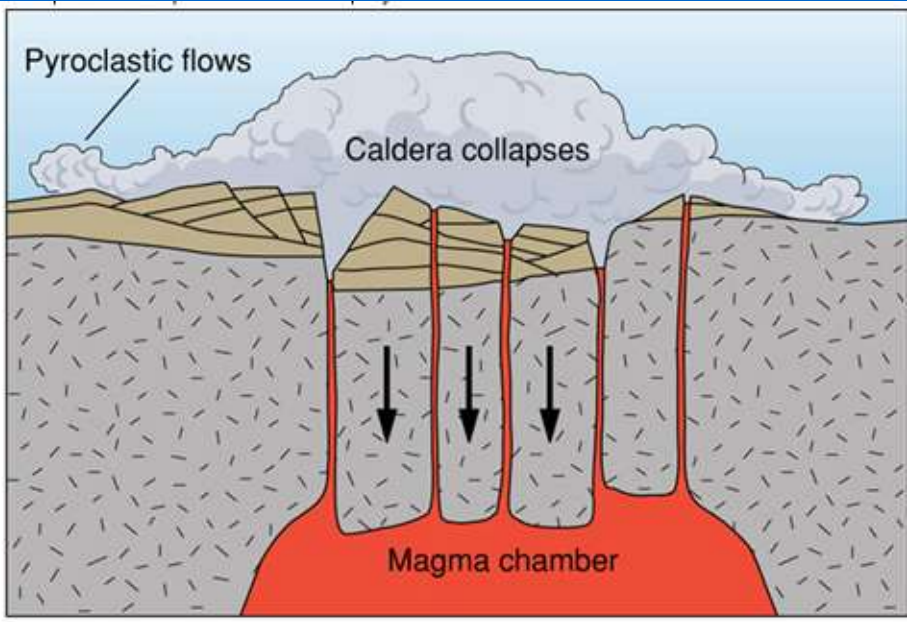
Pyroclastic flows Phillipines

Photo by Chris Newhall, U.S. Geological Survey

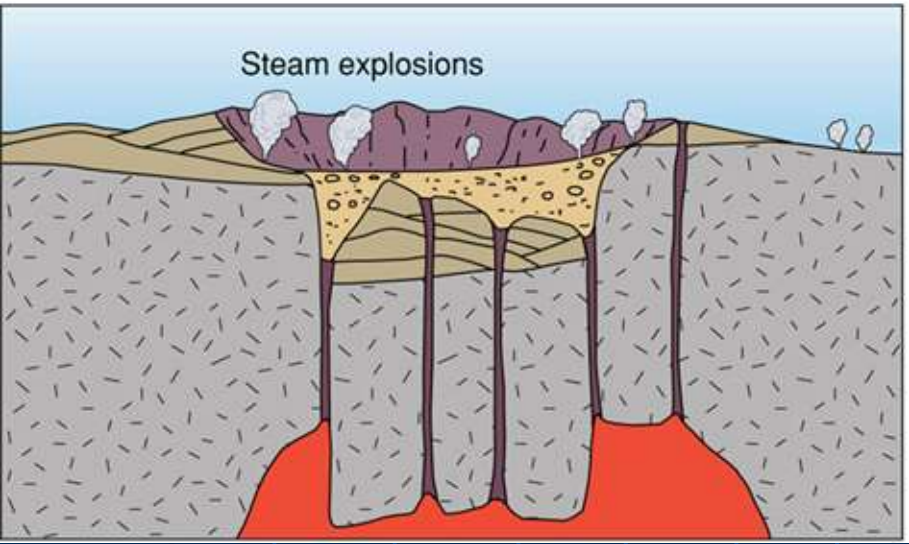
Crater Lake

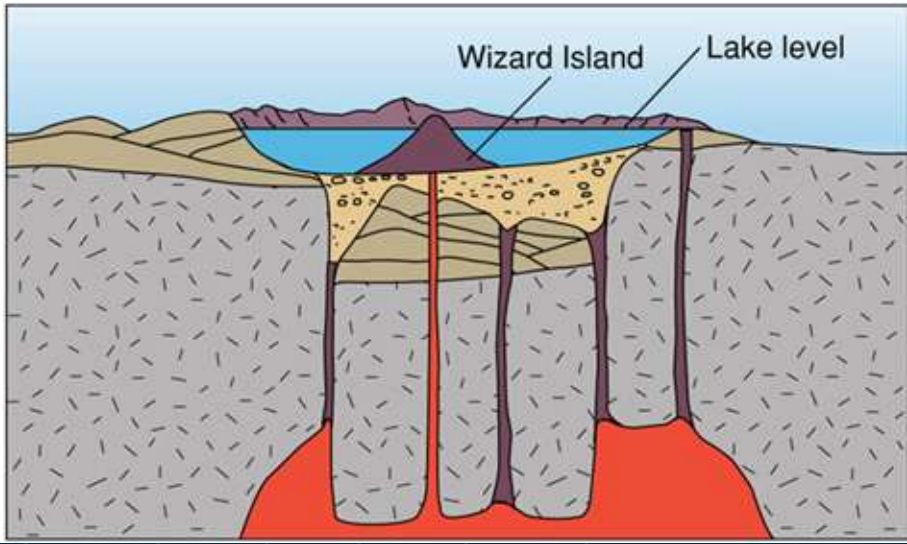


A



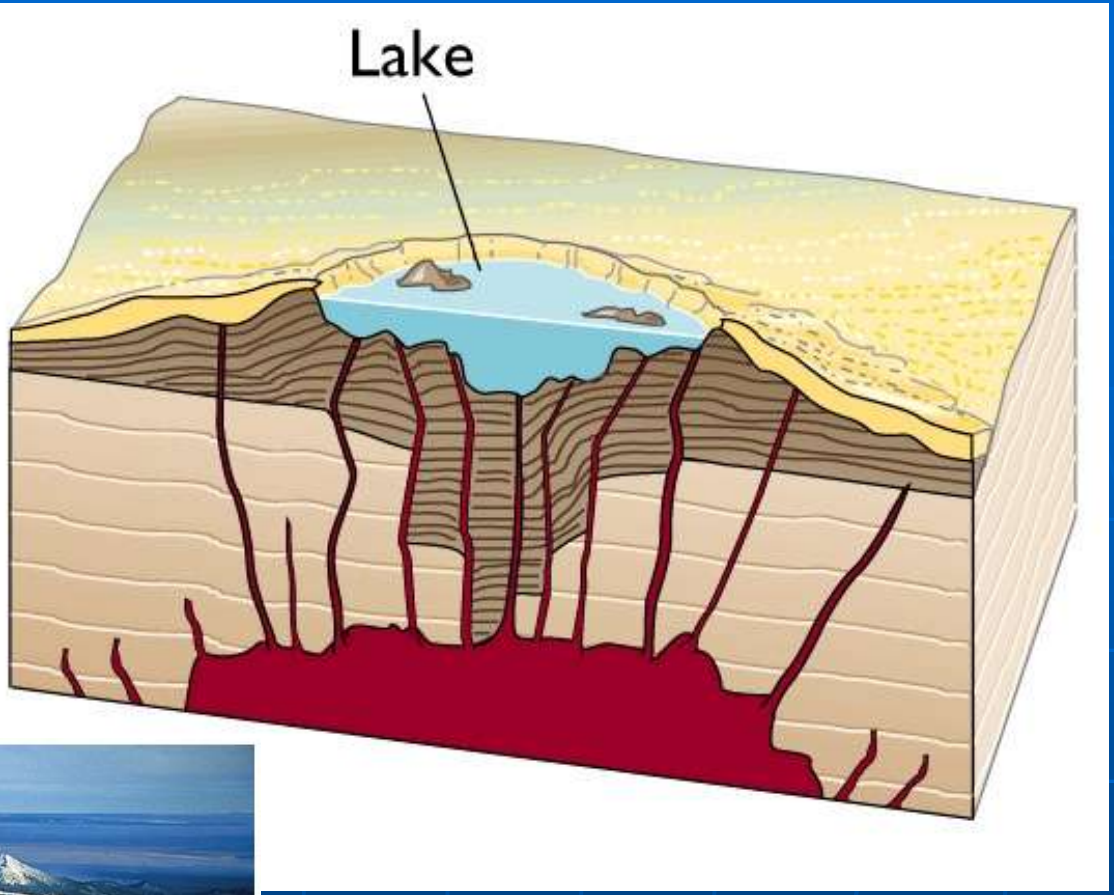
B





Calderas in stratovolcanoes

- Andesitic: Crater Lake, Oregon
- Basaltic: Kilauea, Hawaii



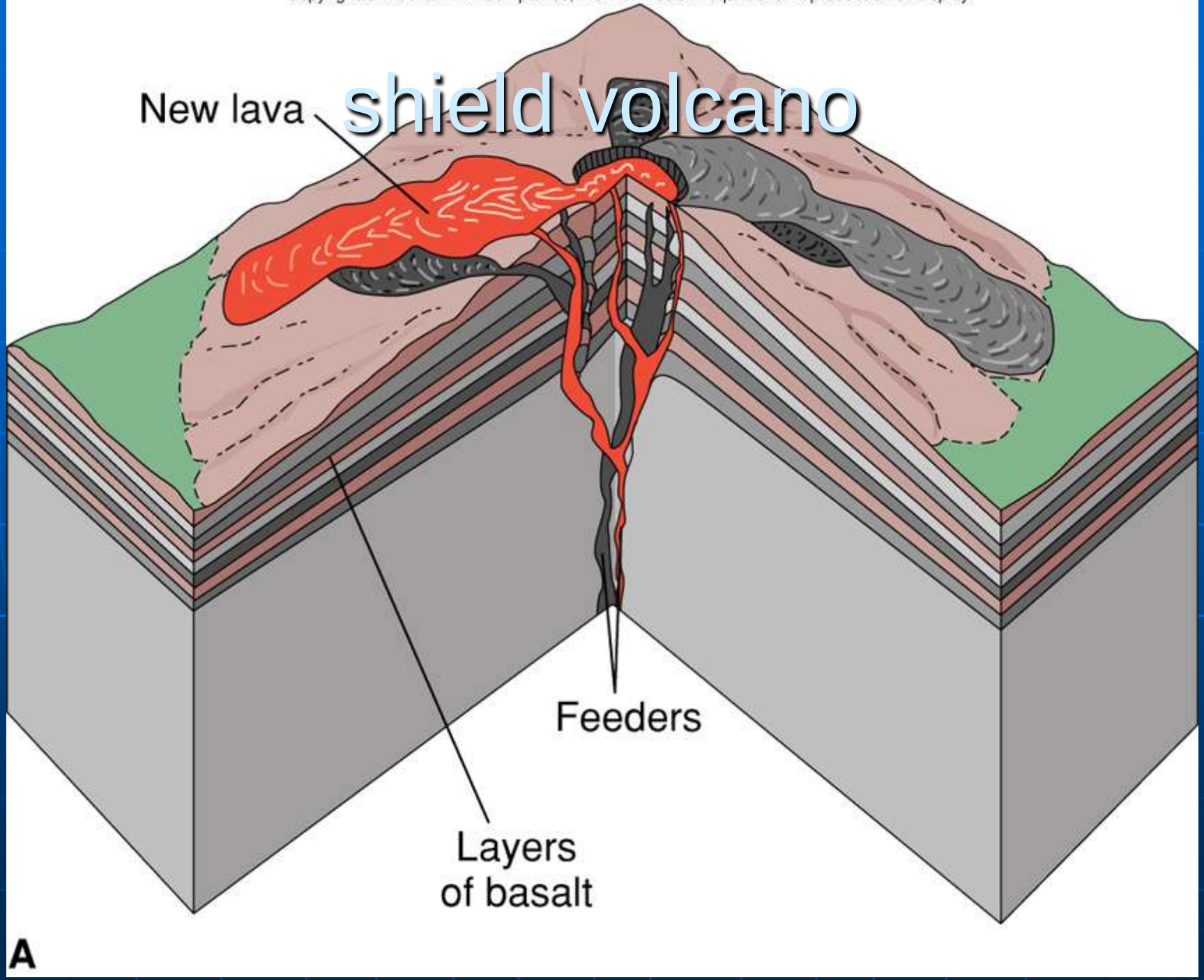
- Crater Lake caldera formed by collapse during & following of massive eruption of ancient Mt. Mazama

Shield Volcanoes

- Have a more fluid and mafic lava (basalt)
  - low viscosities
  - low gas volumes
- Broad gentle **domes**
- Lava travels great distances, spreads thinly
- Most lava emitted from *side fissures*
- Possess a type of *"collapsed calderas"*

Fig. 4.16, pg. 88

shield volcano



Mauna Loa summit caldera

B

Photo by D. W. Peterson, U.S. Geological Survey

Shield Volcanoes

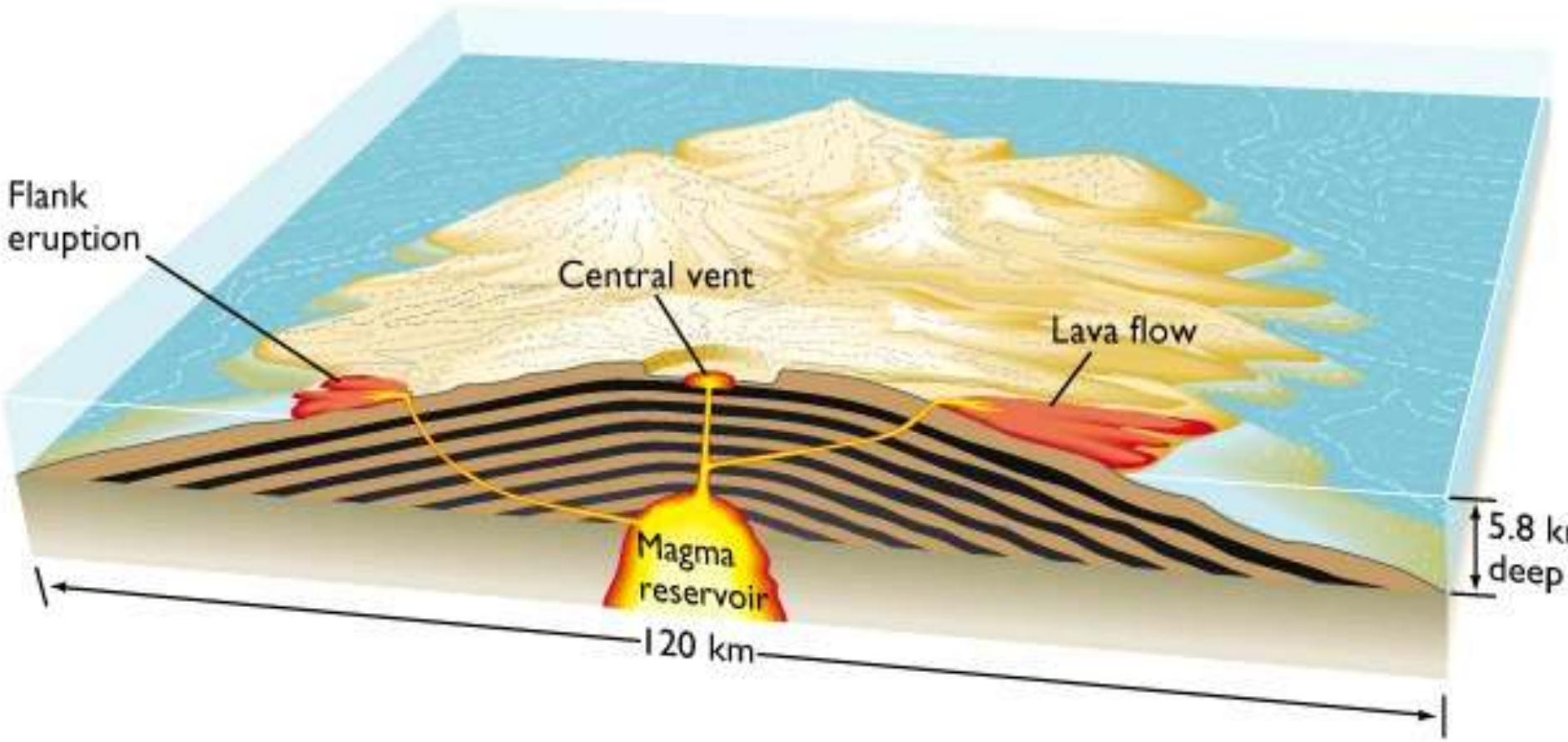
- Cinder Cones
  - Frothy basaltic lava
  - High pressure with a narrow vent
  - Smallish, a few hundred meters high

Fig. 4.20, pg. 89

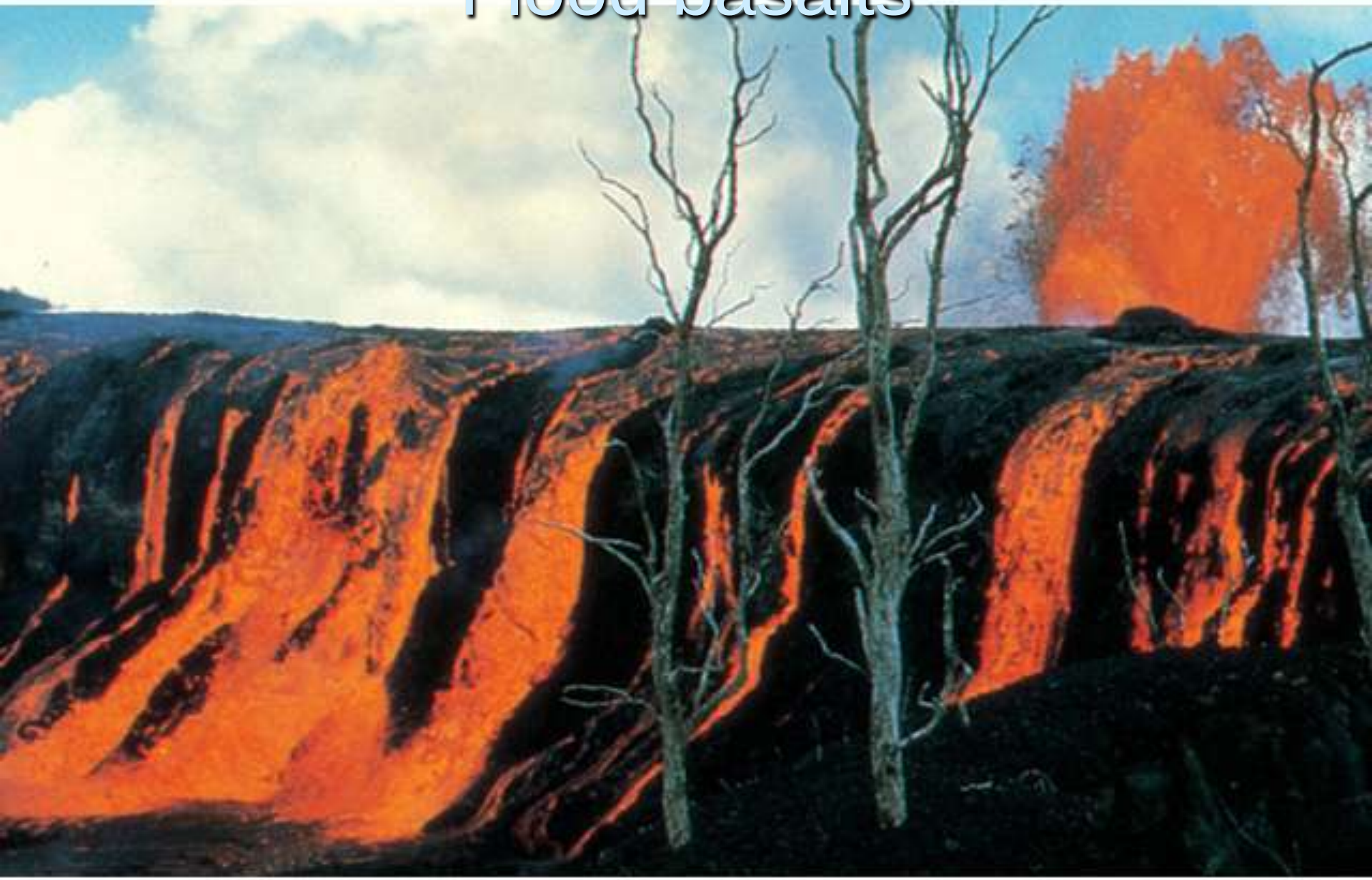
Shield volcanoes

— Gentle slopes

— Basaltic, passive eruptions (e.g., Hawaii)



Flood basalts



B

Photo by D. A. Swanson, U.S. Geological Survey

Hot Spot Volcanism

- Voluminous — driven by upwelling mantle "plumes"
- Oceanic
  - fundamentally basaltic, shield volcanoes and fissure eruptions
  - Hawaii — tracks movement of Pacific plate
- Continental
  - "bimodal" flood basalts and rhyolitic calderas
  - Yellowstone — tracks movement of North American plate

Other Eruption Types

- ***Flood eruptions***
  - Continental lava flows
  - Very fluid (basalts)
  - Extremely large volume
  - Create extensive ***lava plateaus***
  - Correspond with largest ***mass extinction event***
- *Submarine eruptions*
  - Nearly always basaltic
  - Mid-ocean ridge eruptions
  - Pillow basalts

Fig. 4.27, pg. 96

Columbia river flood basalts

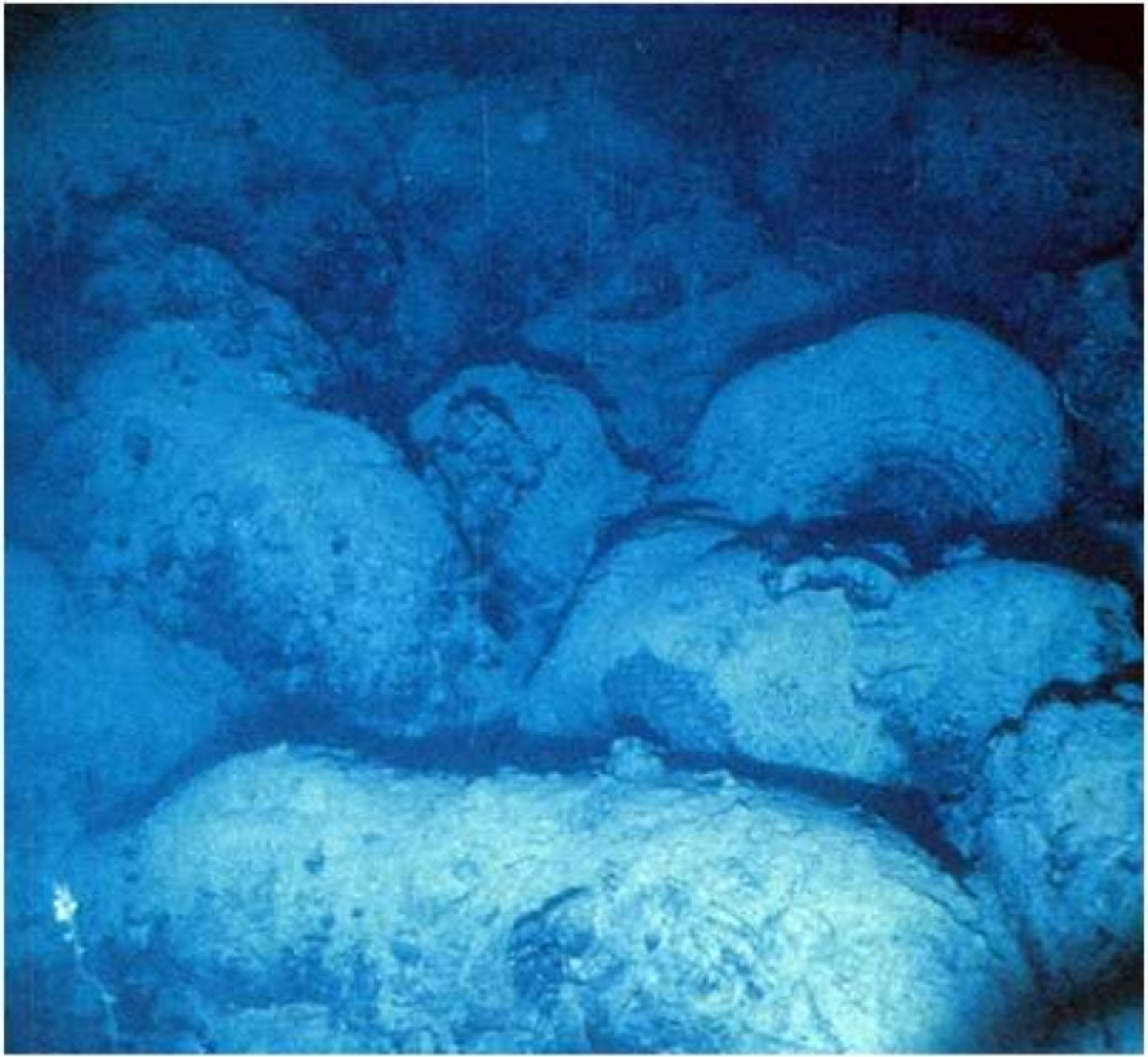
Pillow basalts

Figs. 4-30, -31, pg. 98

Lava Floods

Submarine Eruptions

- Pillow Basalts



Pillow basalt, Iceland

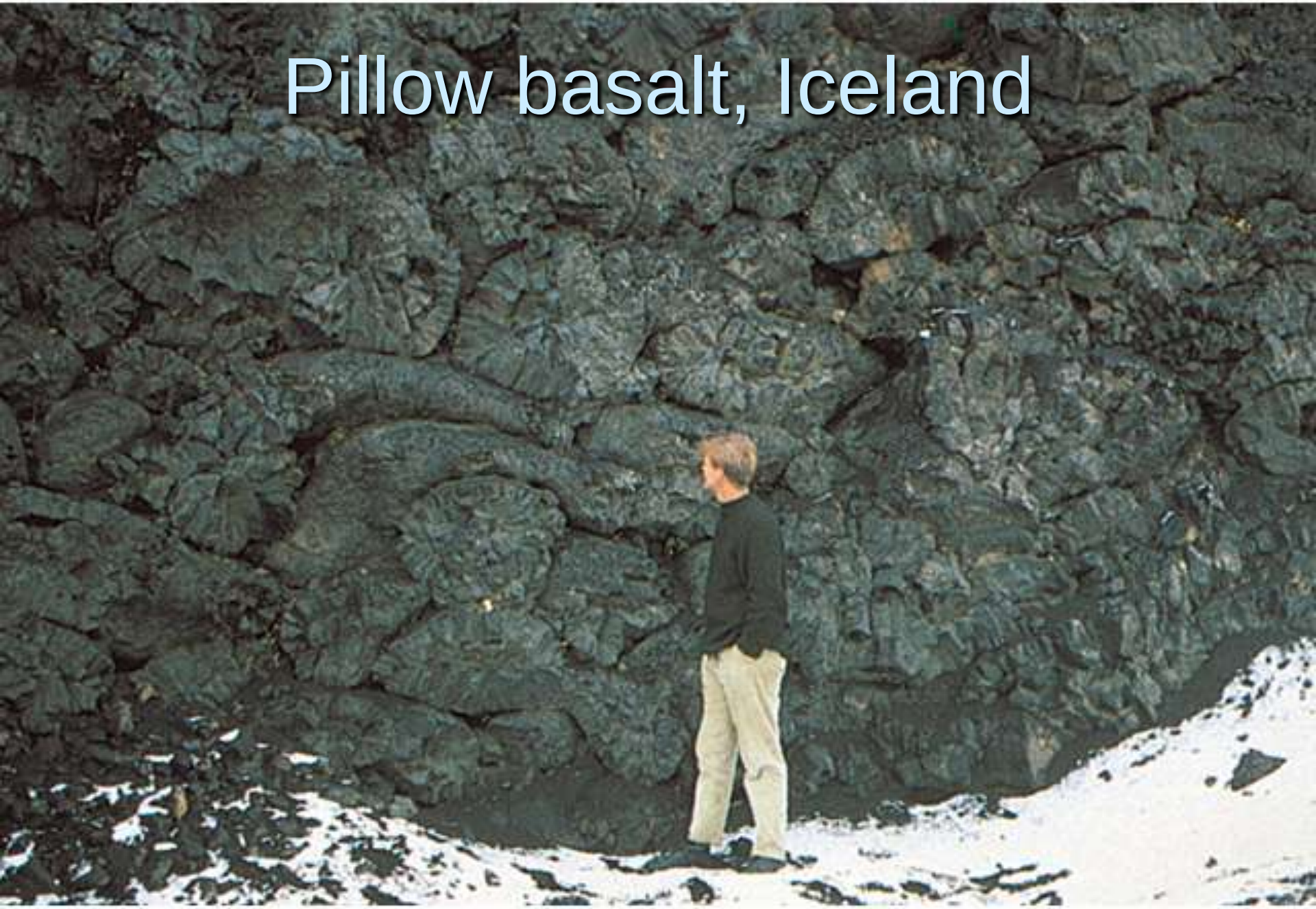


Photo by R. W. Decker

pahoehoe

Photo by D. W. Peterson, U.S. Geological Survey

Photo by J. D. Griggs, U.S. Geological Survey

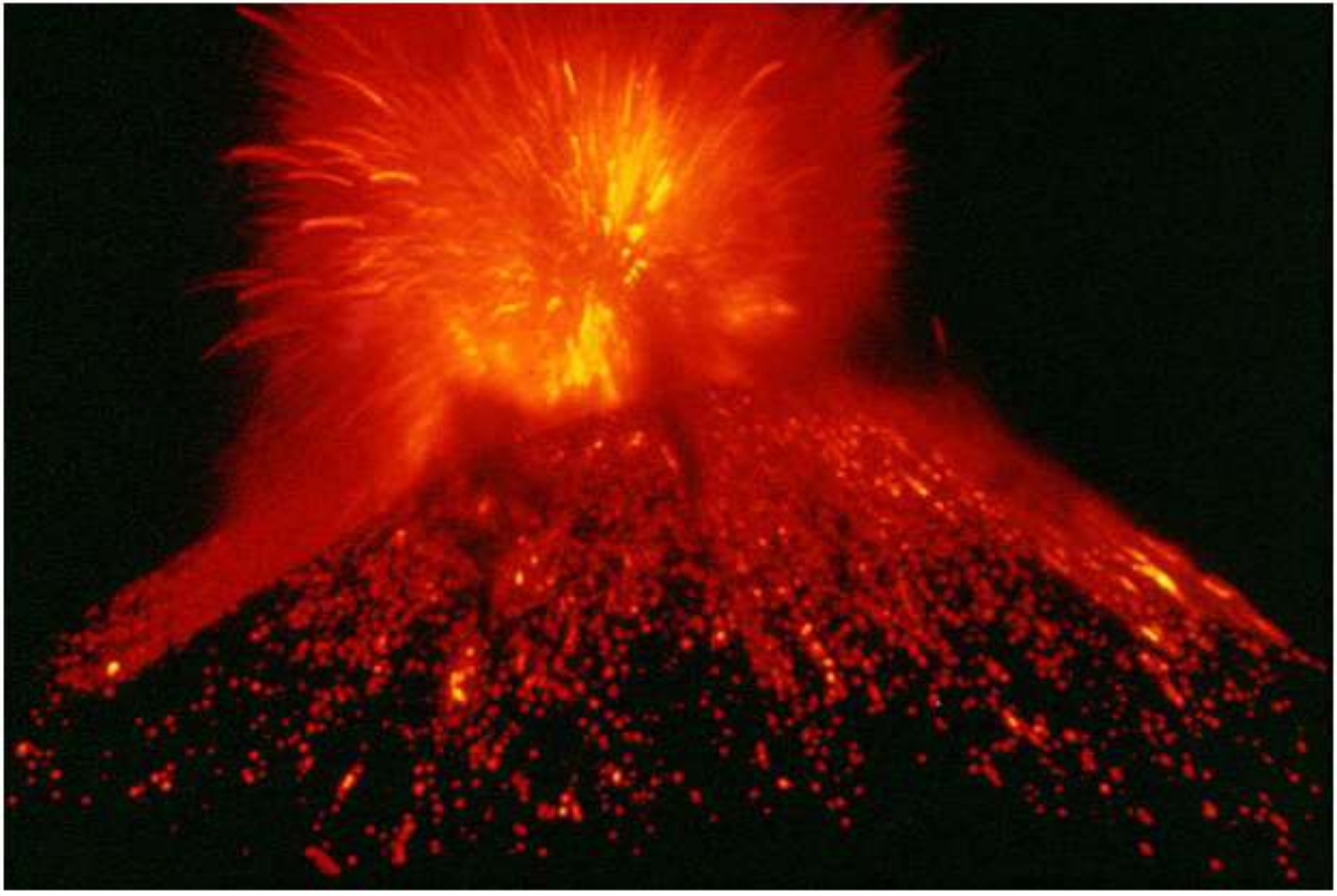
aa

pahoehoe

Spatter cone

Photo by J. B. Judd, U.S. Geological Survey

Cinder cone



Olympus Mons, Mars

Photo by NASA

Io, Jupiter's moon: S volcanoes

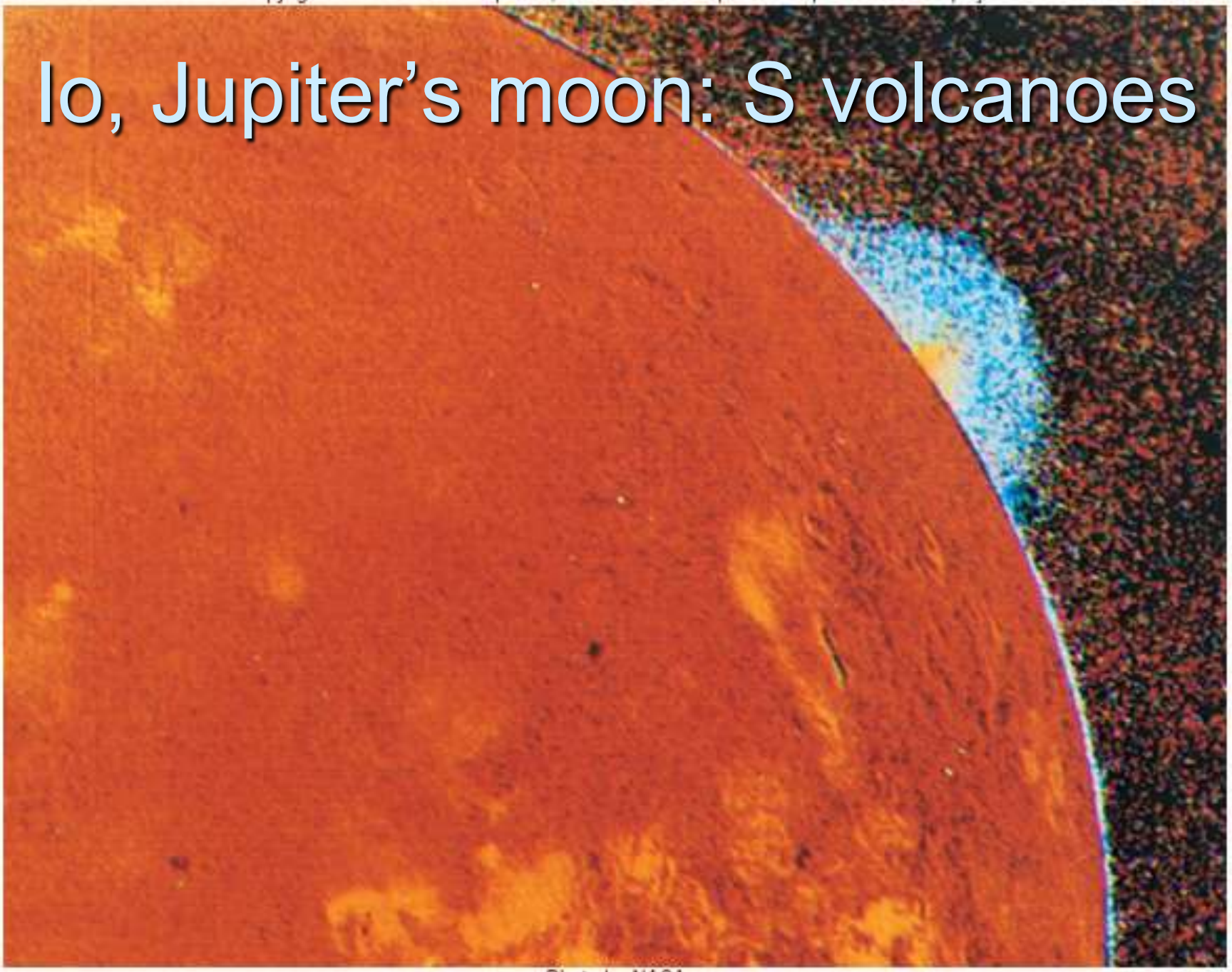
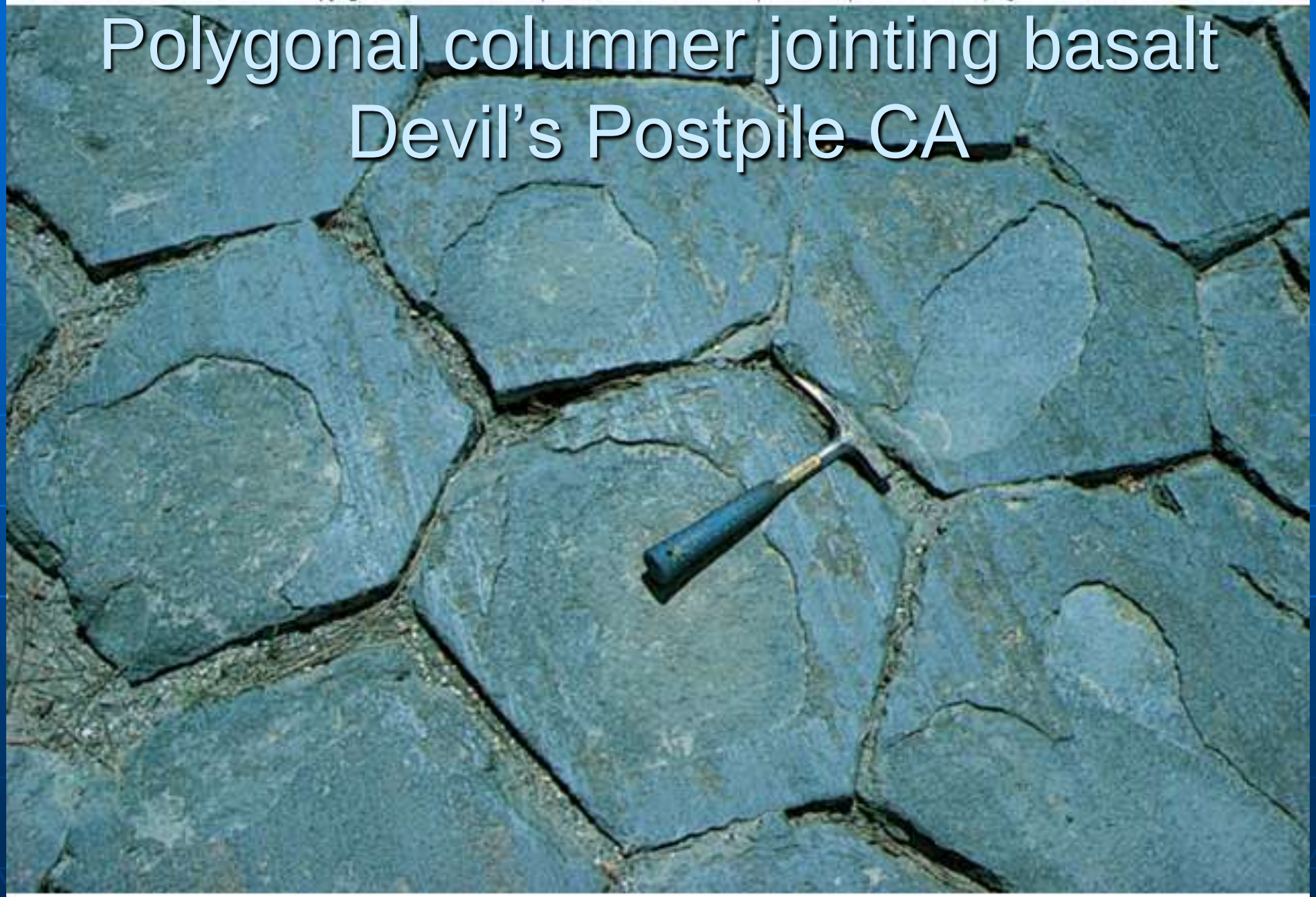


Photo by NASA

Columbia R. basalt flows

Photo by P. Weis, U.S. Geological Survey

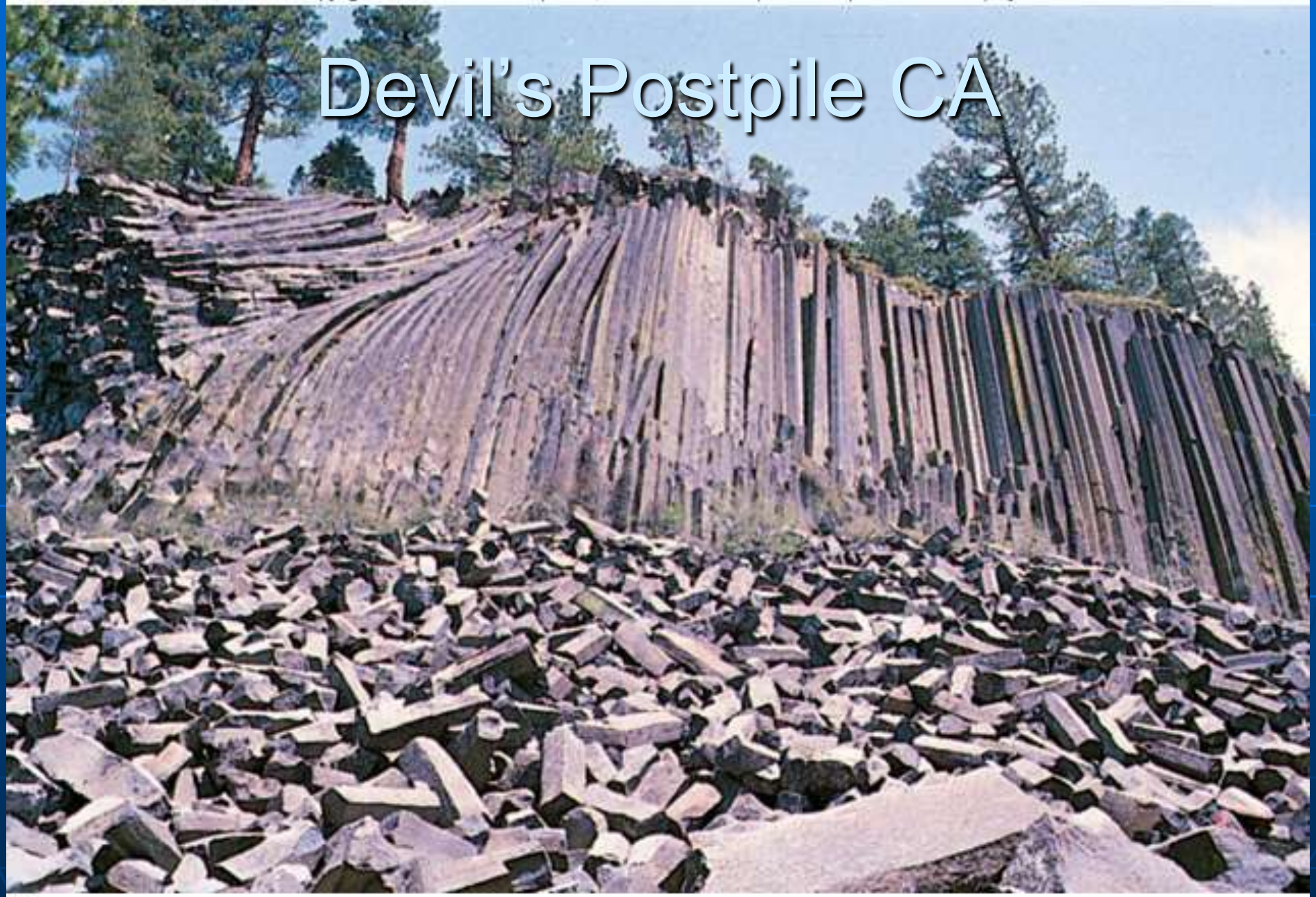
Polygonal columner jointing basalt Devil's Postpile CA



A

Photo by C. C. Plummer

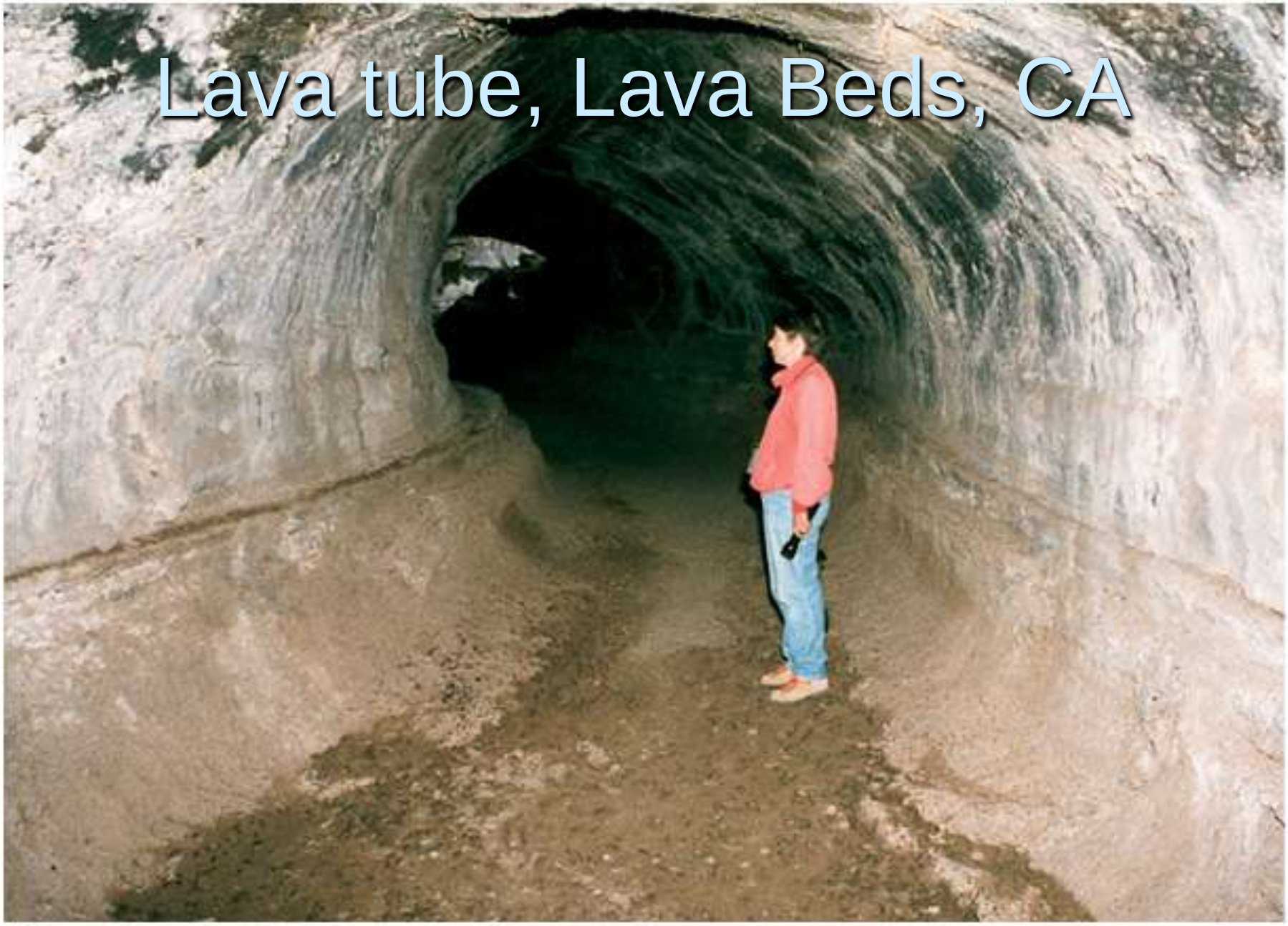
Devil's Postpile CA



B

Photo by C. C. Plummer

Lava tube, Lava Beds, CA



B

Photo by C. C. Plummer

Lava Tube

Volcanic Materials

- Lavas — move (mainly) as massive magma
  - Massive to brecciated flows (pahoehoe, aa, pillows)
- Pyroclastics — fragmented magma / rock
  - Ash (and lapilli), cinders, bombs (increasing size)
  - Pyroclastic flows ("ash flows" or "ignimbrites" can be welded by heat, depending on size)
- Volcaniclastics — reworked, mainly by water
  - Lahars / mudflows — start on or near volcano
  - Epiclastic rocks (reworked volcanic sands / muds)

Table 4.1 Summary of Textures in Volcanic Rocks

Name	Description
Fine-grained (adjective)	Mosaic of interlocking minerals that are smaller than 1 mm.
Porphyritic (adjective)	Some crystals, phenocrysts, are larger than 1 mm (usually considerably larger). Most grains are smaller than 1 mm. Or phenocrysts are enclosed in glass.
Obsidian	Glass. Atoms are disordered.
Vesicular (adjective)	Holes in rock due to trapped gas.
Pumice	Frothy glass.
Tuff	Consolidated fine pyroclastic material.
Volcanic breccia	Consolidated pyroclastic debris that includes blocks or bombs.

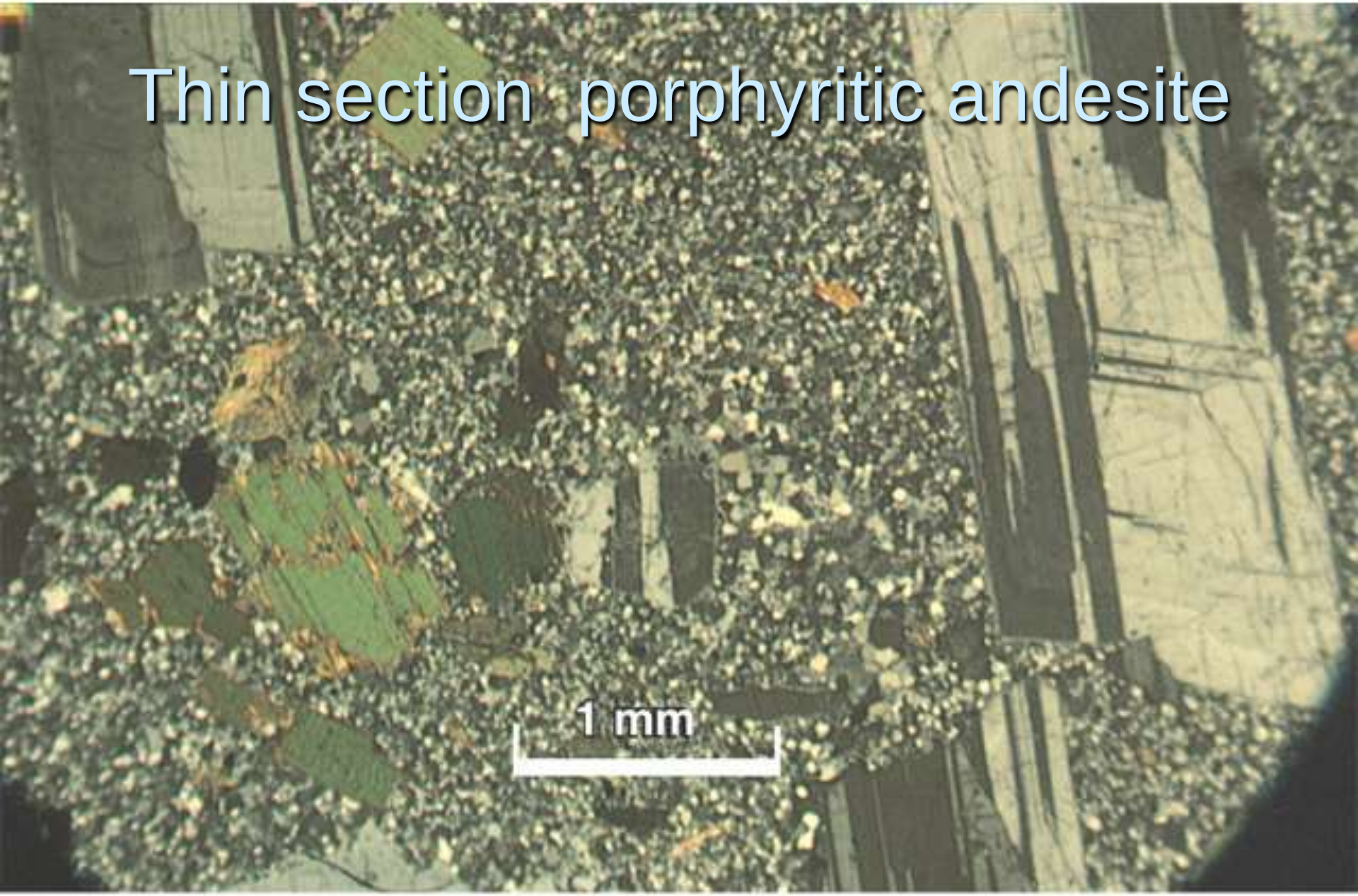
Obsidian

Photo by C. C. Plummer

A

Photo by C. C. Plummer

Thin section porphyritic andesite



B

Photo by C. C. Plummer

Photo by C. C. Plummer

Photo by C. C. Plummer

Volcanic bombs

Photo by C. C. Plummer

Photomicrograph tuff

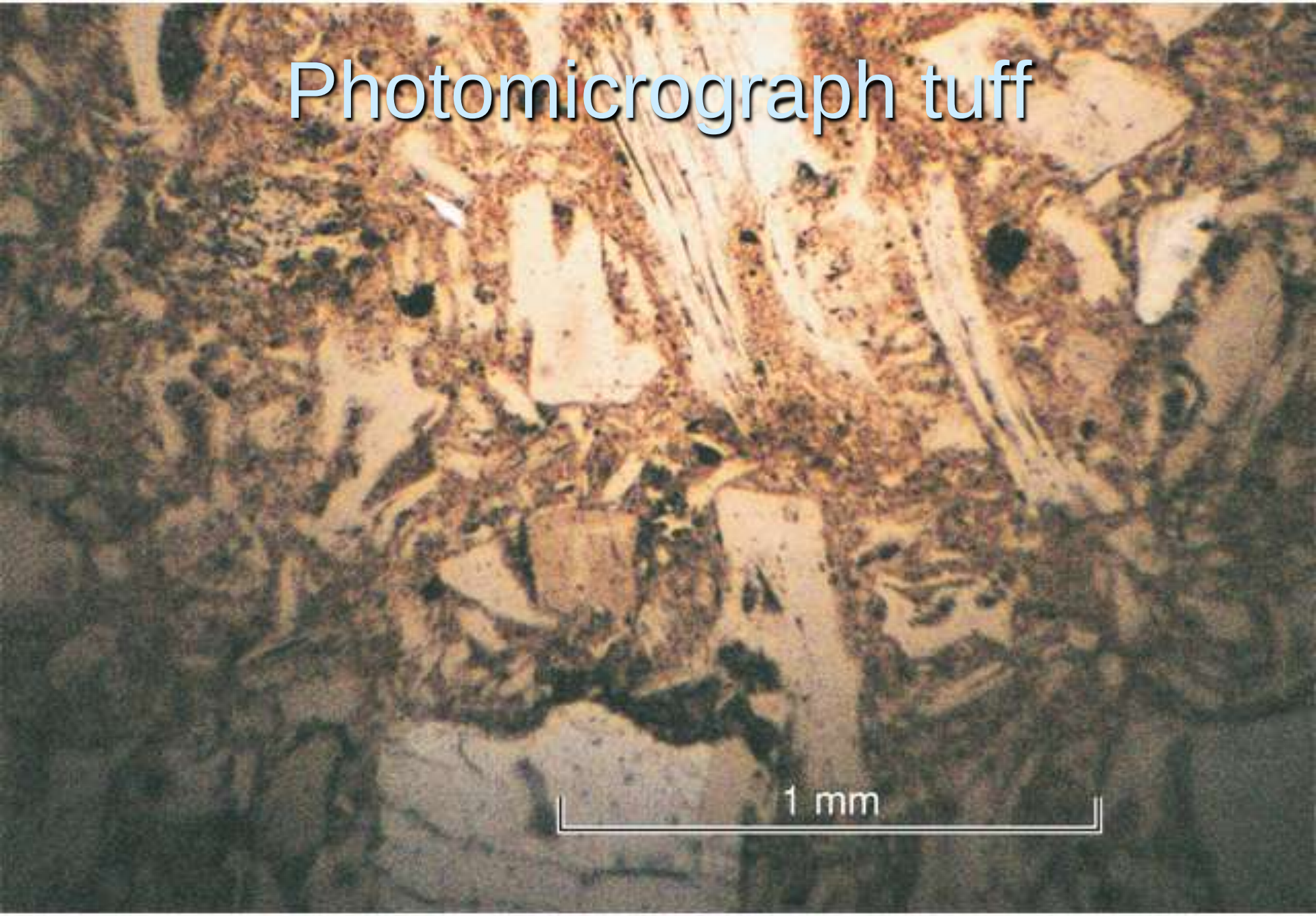
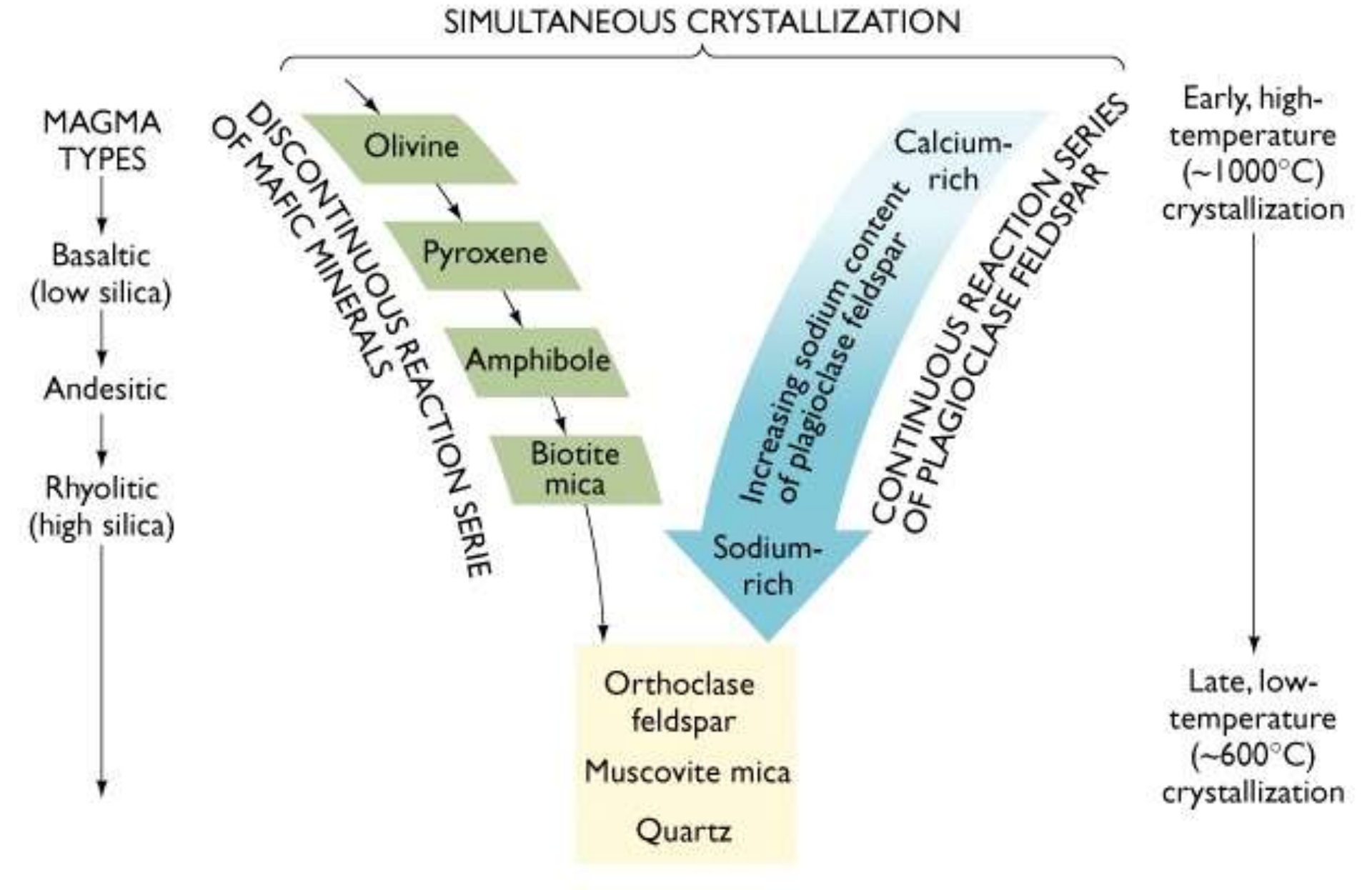


Photo by C. C. Plummer

Bowen's Reaction Series



Py ow

Cinder cones and basalt flows

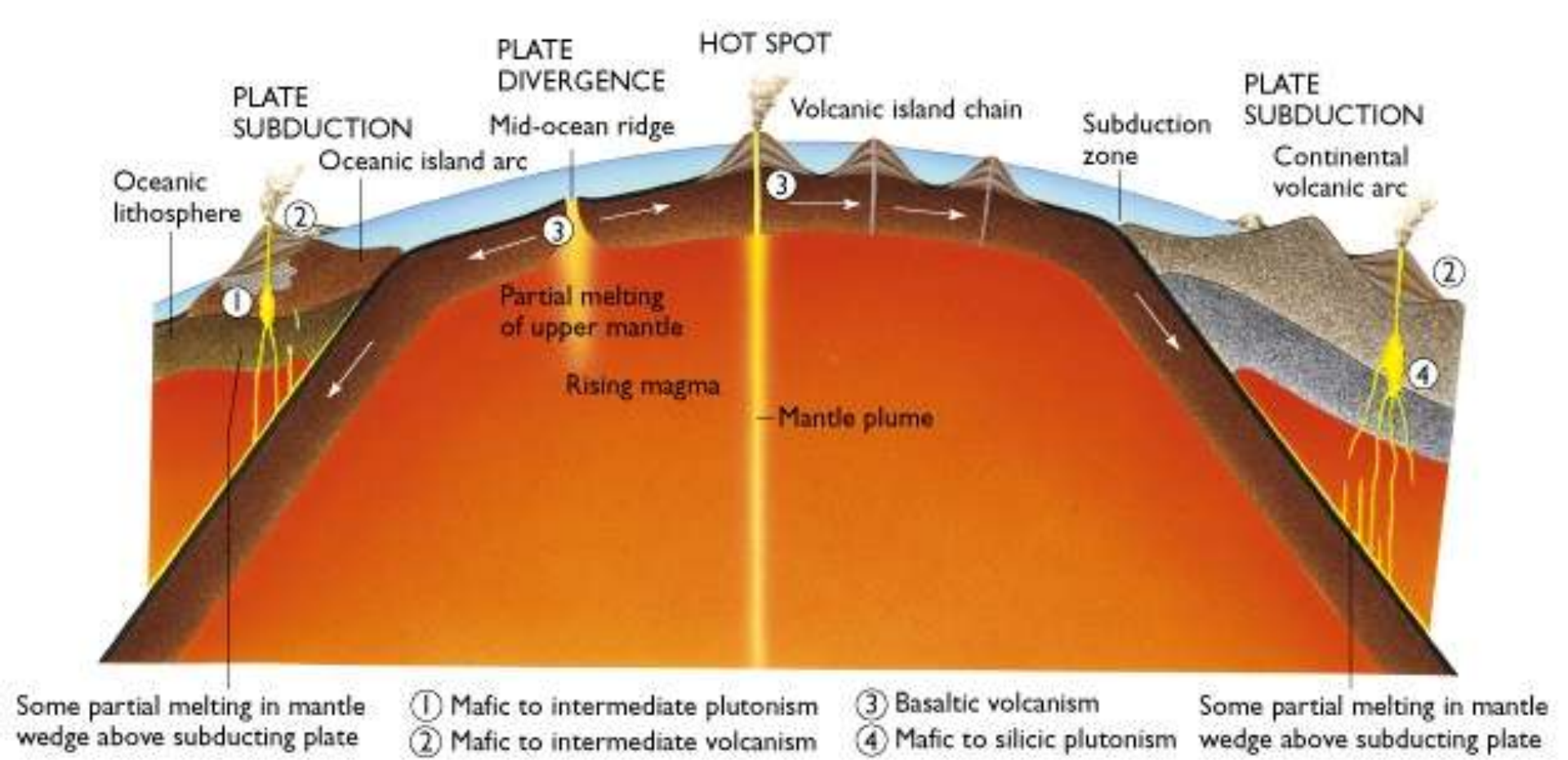
Stratovolcanoes and Calderas

- Stratovolcanoes built of multiple lava flows and pyroclastic rocks ("strata")
  - Steep cones of arc (andesitic) volcanism
  - Gentle cones of shield (basaltic) volcanism
- Calderas are collapse features formed over rapidly evacuated magma chambers
  - May form late in the history of a stratovolcano
  - Most common over rhyolitic magma chamber, commonly without central volcano precursor

Andesitic stratovolcanoes

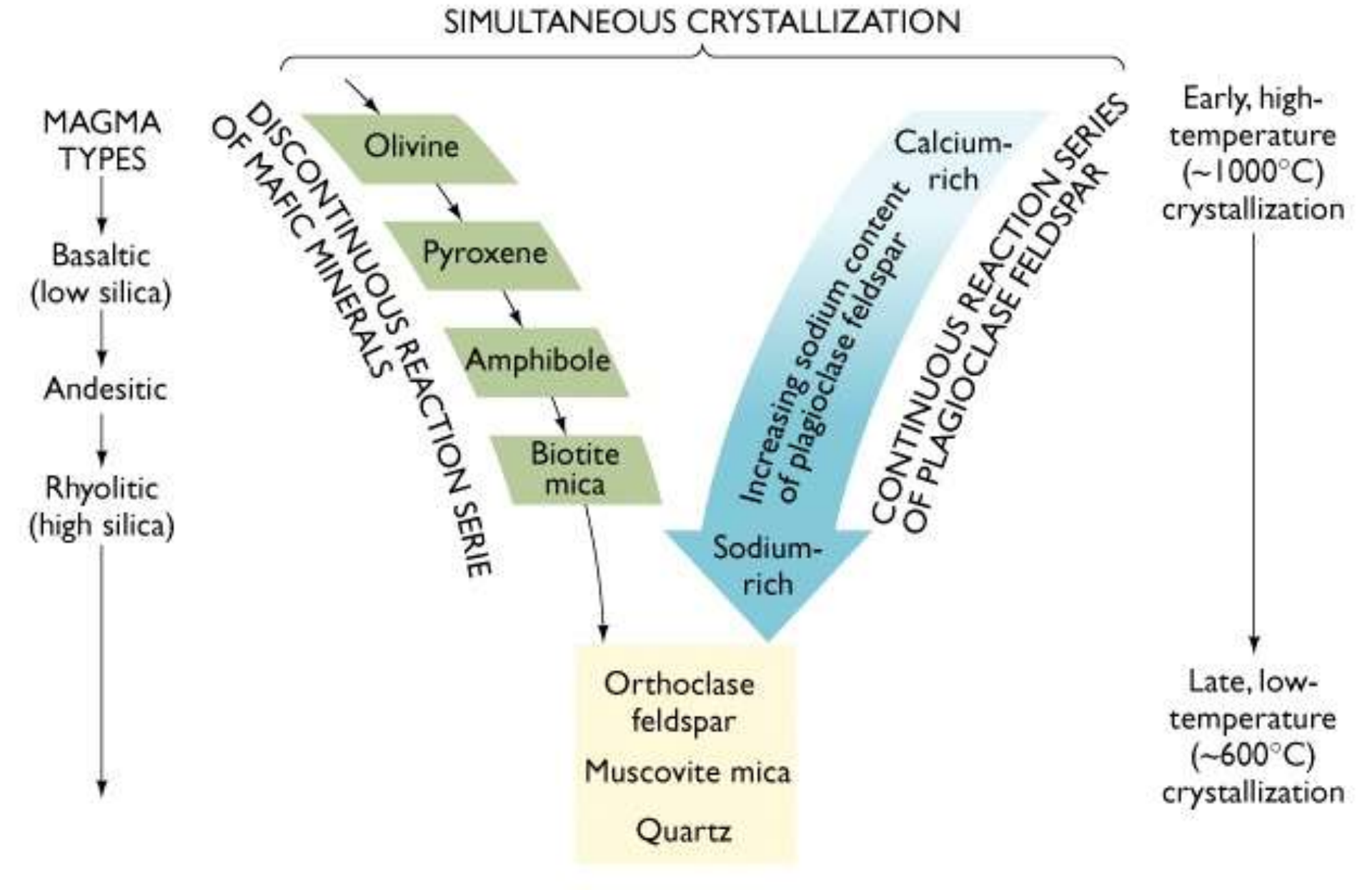
— Composite (many eruptions), steep sided

— Commonly violent (e.g., Mount St. Helens)



Tectonic settings for magmatism

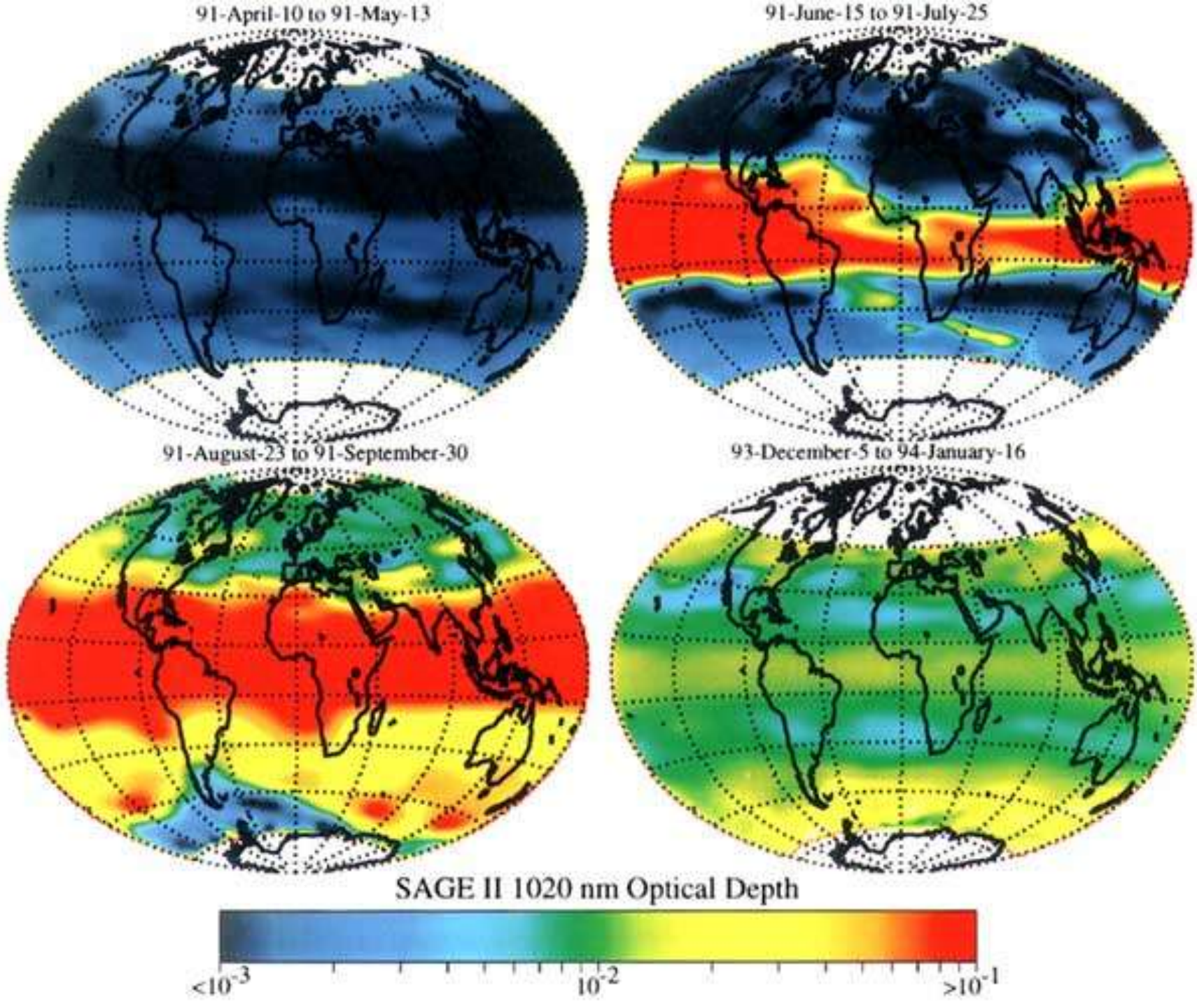
Bowen's Reaction Series

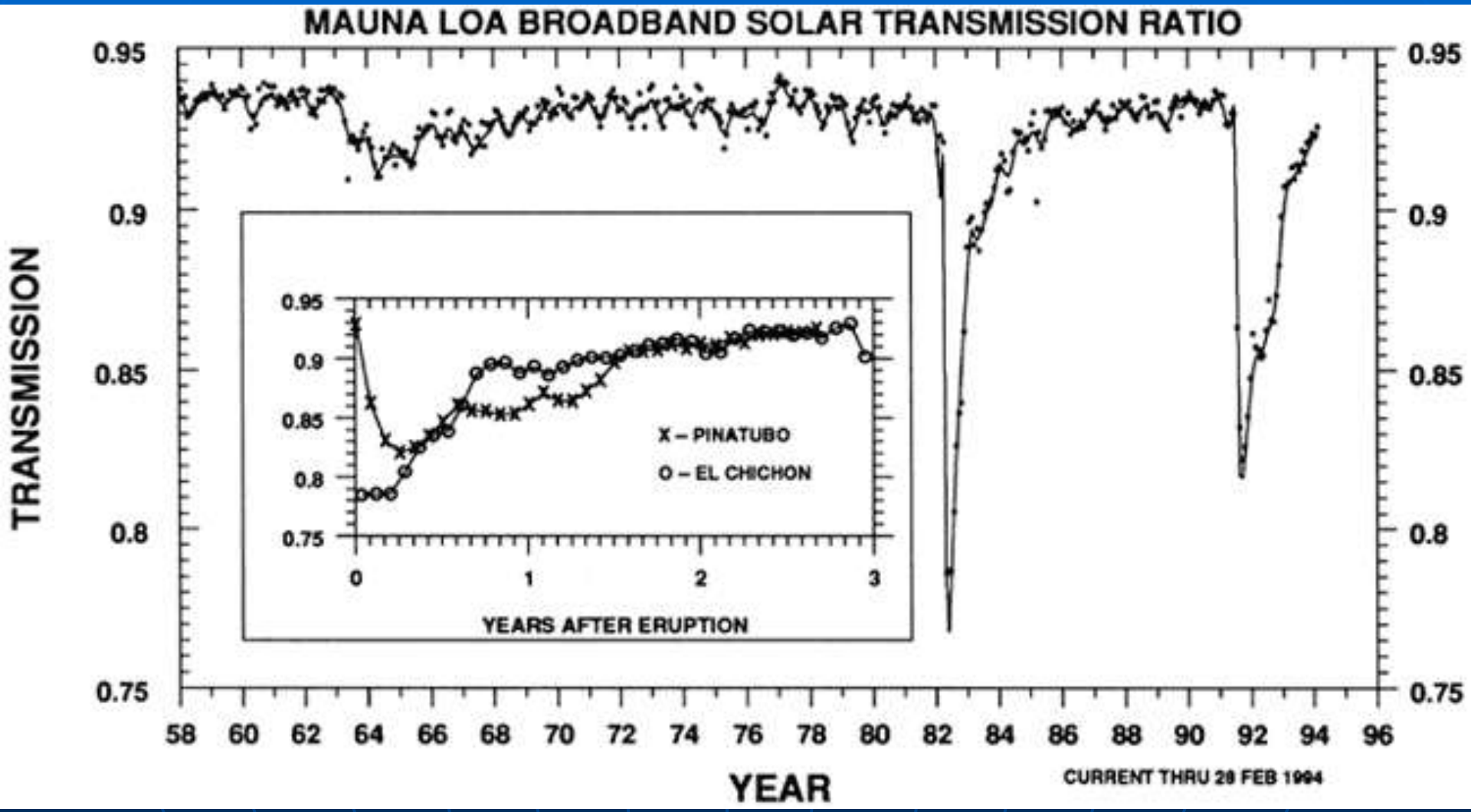


Volcanoes and People

- Hazards:
  - Lavas, pyroclastics, lahars, gases
- Resources:
  - Geothermal energy (heating, electricity)
  - Mineral deposits are ancient equivalent (seafloor & terrestrial examples)
  - Important for aquifers and soils
- Climate:
  - dust and especially gases (CO_2, SO_2, H_2S) from large eruptions impact climate

Mt. Pinatubo 1991


91-April-10 to 91-May-13
91-June-15 to 91-July-25
91-August-23 to 91-September-30
93-December-5 to 94-January-16
SAGE II 1020 nm Optical Depth
<10^-3
10^-2
>10^-1


MAUNA LOA BROADBAND SOLAR TRANSMISSION RATIO
TRANSMISSION
0.95
0.9
0.85
0.8
0.75
58 60 62 64 66 68 70 72 74 76 78 80 82 84 86 88 90 92 94 96
YEAR
CURRENT THRU 28 FEB 1994
X – PINATUBO
O – EL CHICHON
0 1 2 3
YEARS AFTER ERUPTION

Summary

- Types of volcanic deposits and eruptions
- Types of volcanoes (one or many eruptions)
- Controls on volcanic eruptions and volcanoes — magma characteristics, tectonic setting
- Societal / global impact of volcanism