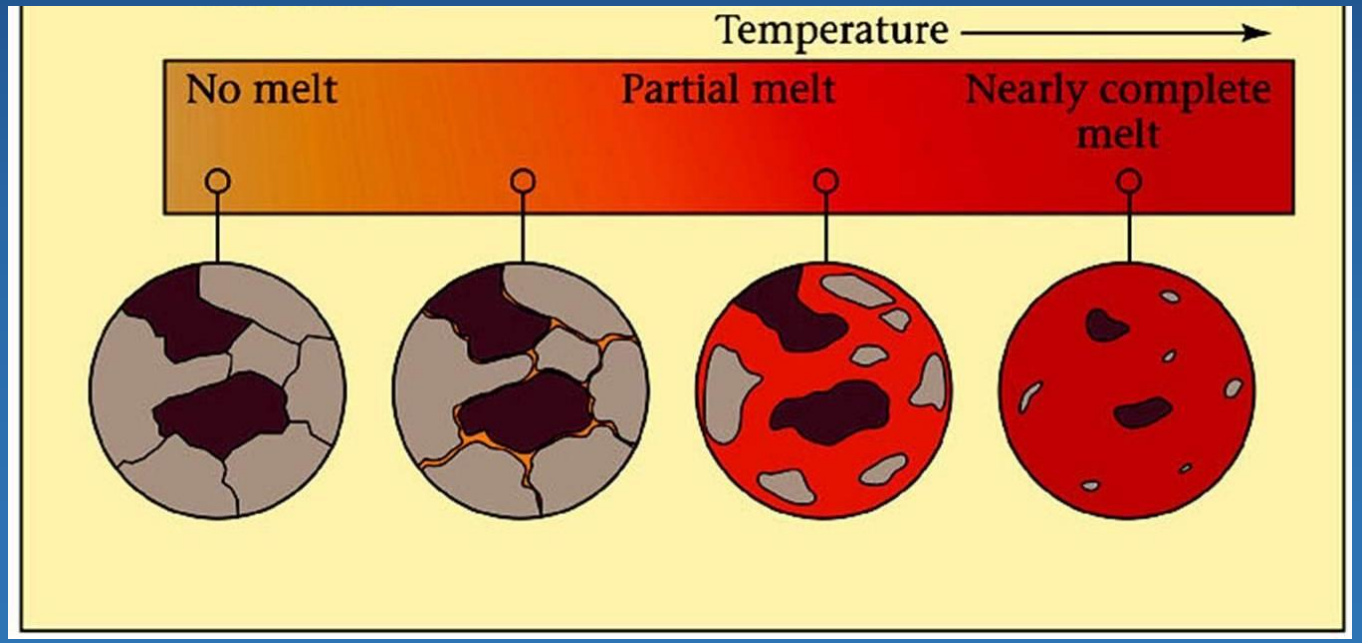
Why are there different types of Igneous Rocks?

- Source rock
- Crystal Fractionation
- Partial Melting
- Assimilation
- Magma mixing

Partial Melting

- Minerals with lowest melting temperature melt first
- Partial melting produces melts with more silica
- Remove melt:
  - Silica-rich melt
  - Mafic residue



Bowen's Reaction Series

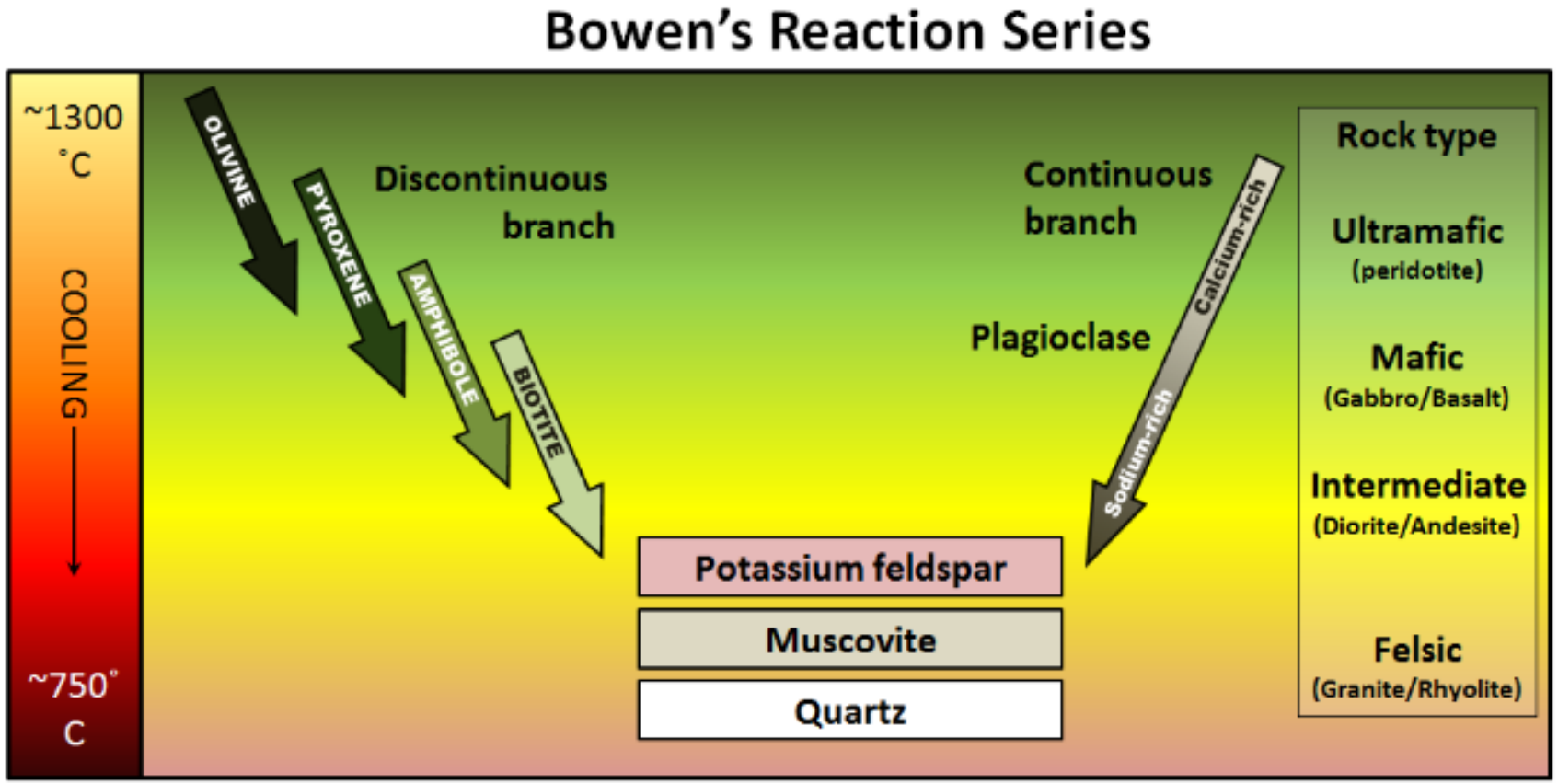
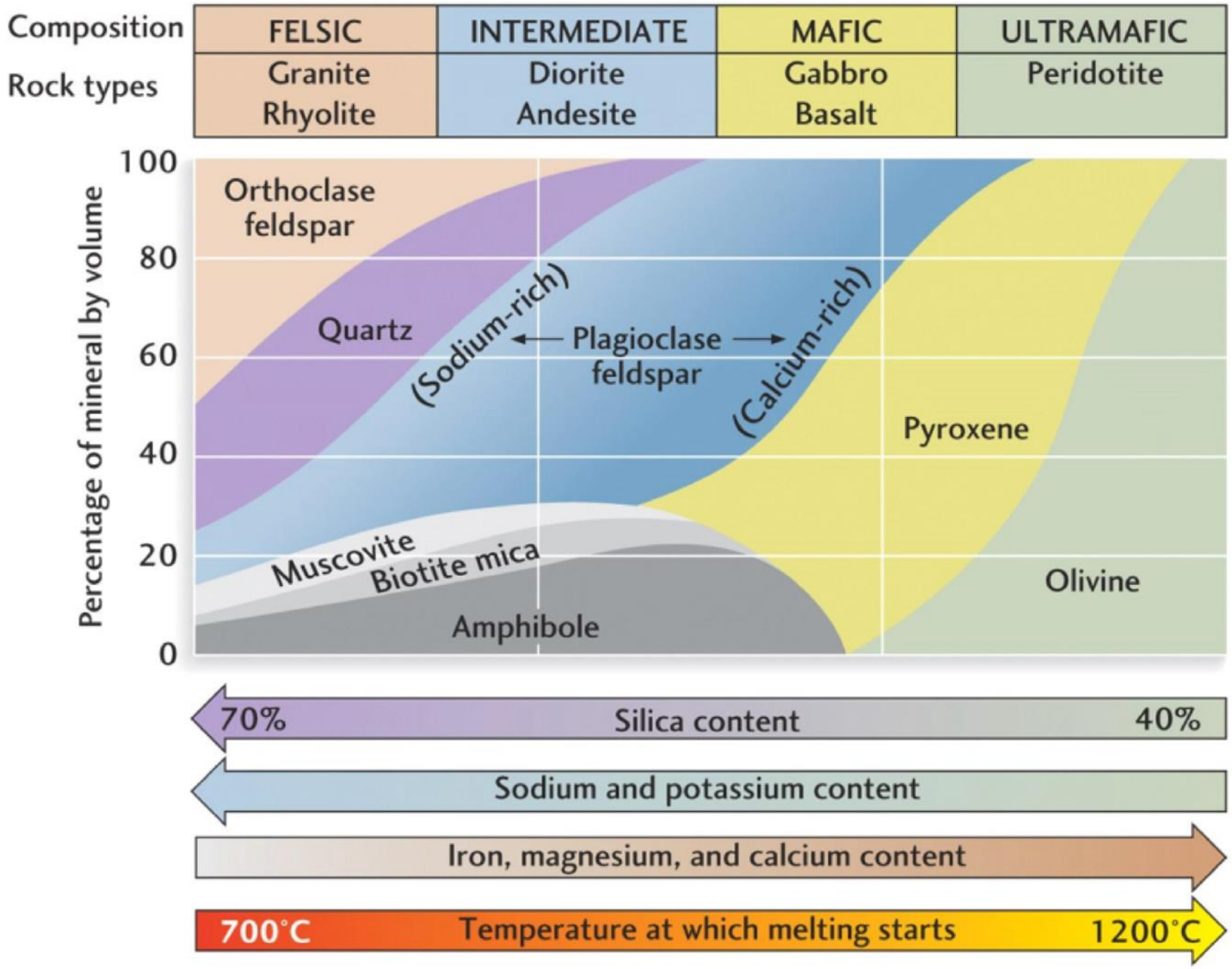
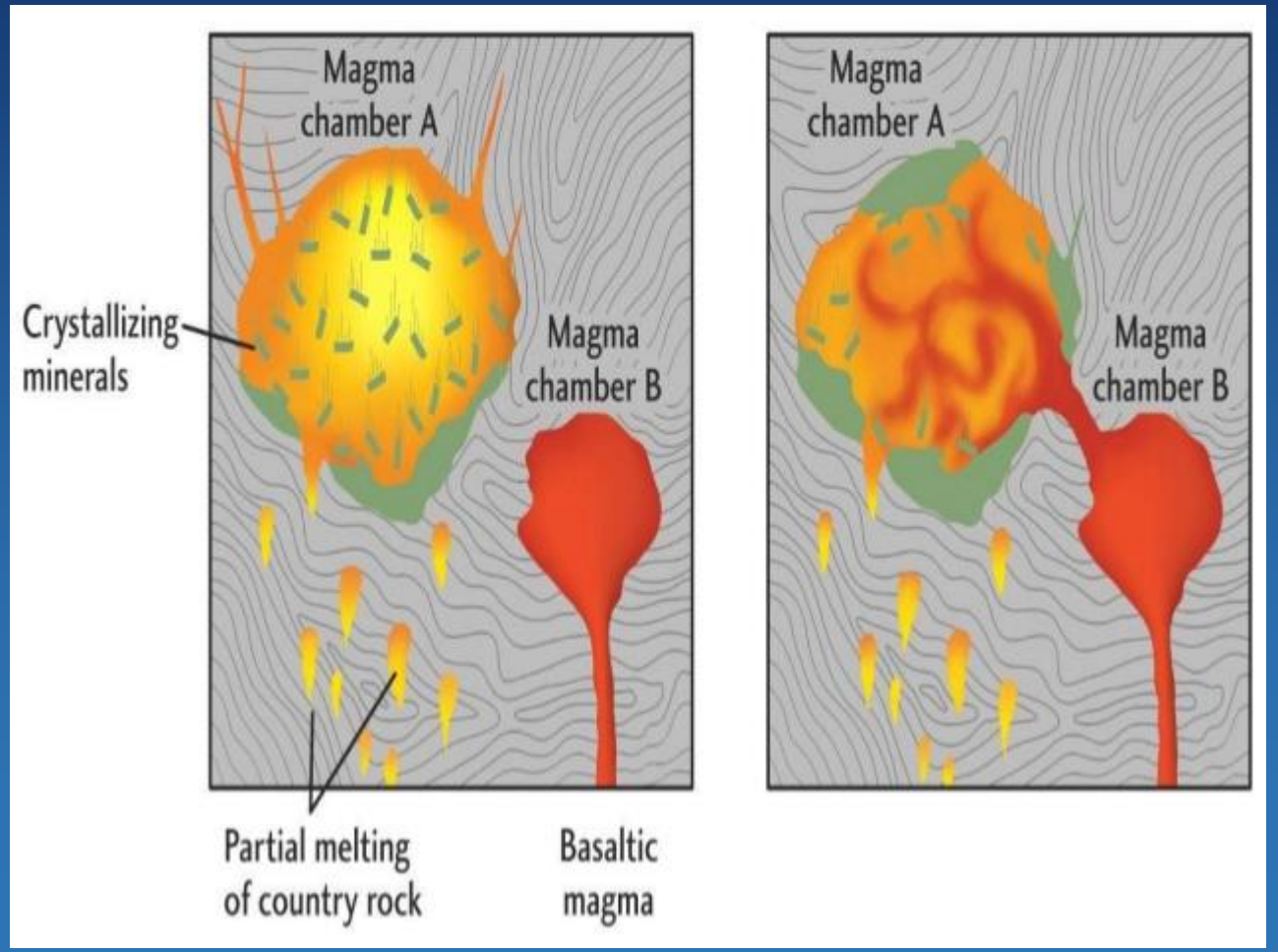


Figure 3.3.1 The Bowen reaction series describes the process of magma crystallization.


Composition
FELSIC
INTERMEDIATE
MAFIC
ULTRAMAFIC
Rock types
Granite
Rhyolite
Diorite
Andesite
Gabbro
Basalt
Peridotite
Percentage of mineral by volume
100
80
60
40
20
0
Orthoclase feldspar
Quartz
(Sodium-rich)
Plagioclase feldspar
(Calcium-rich)
Pyroxene
Muscovite
Biotite mica
Amphibole
Olivine
70%
Silica content
40%
Sodium and potassium content
Iron, magnesium, and calcium content
700°C
Temperature at which melting starts
1200°C

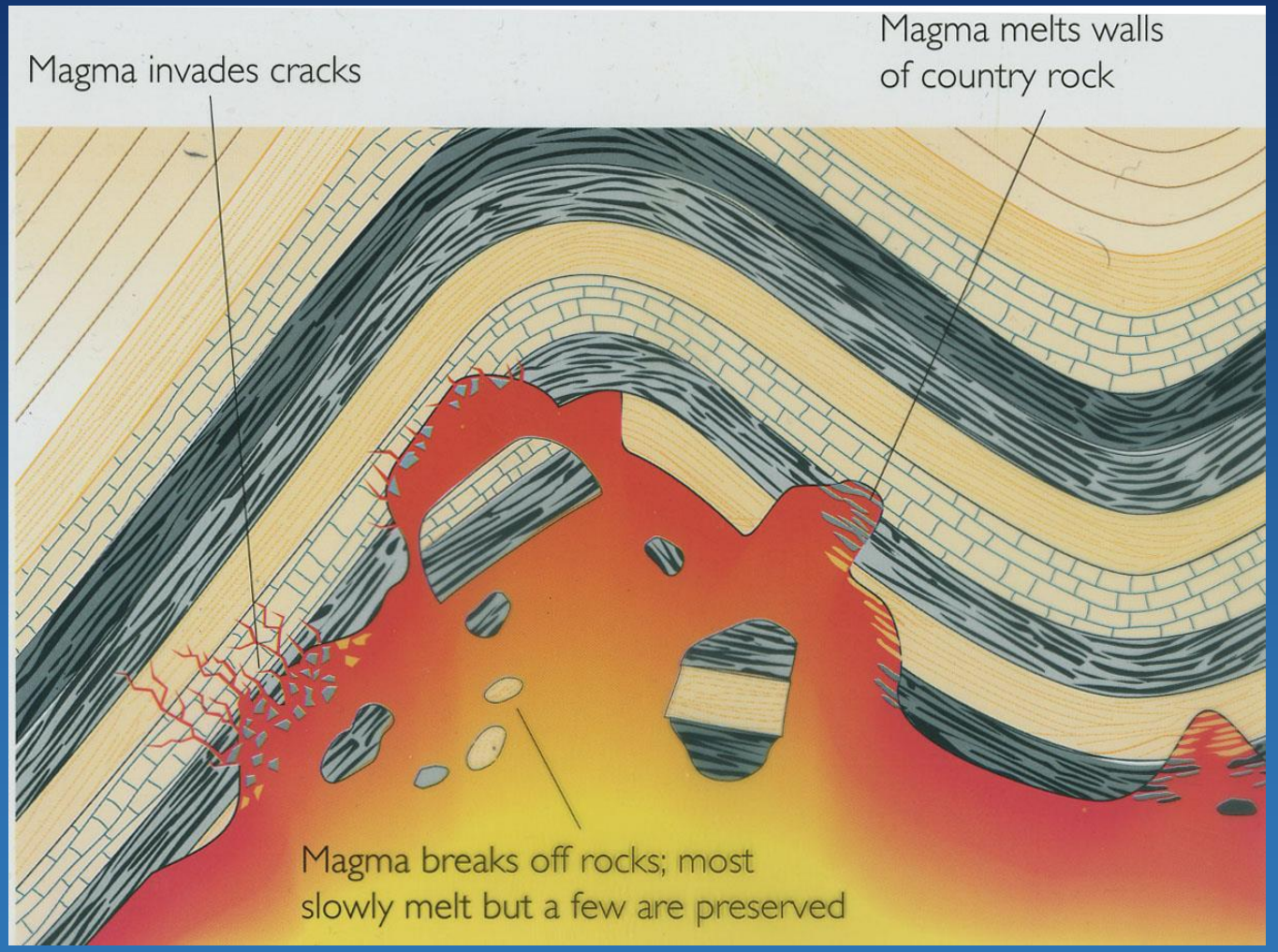
Magma Mixing

- Magmas of different compositions mix together, producing a magma of intermediate composition



Assimilation

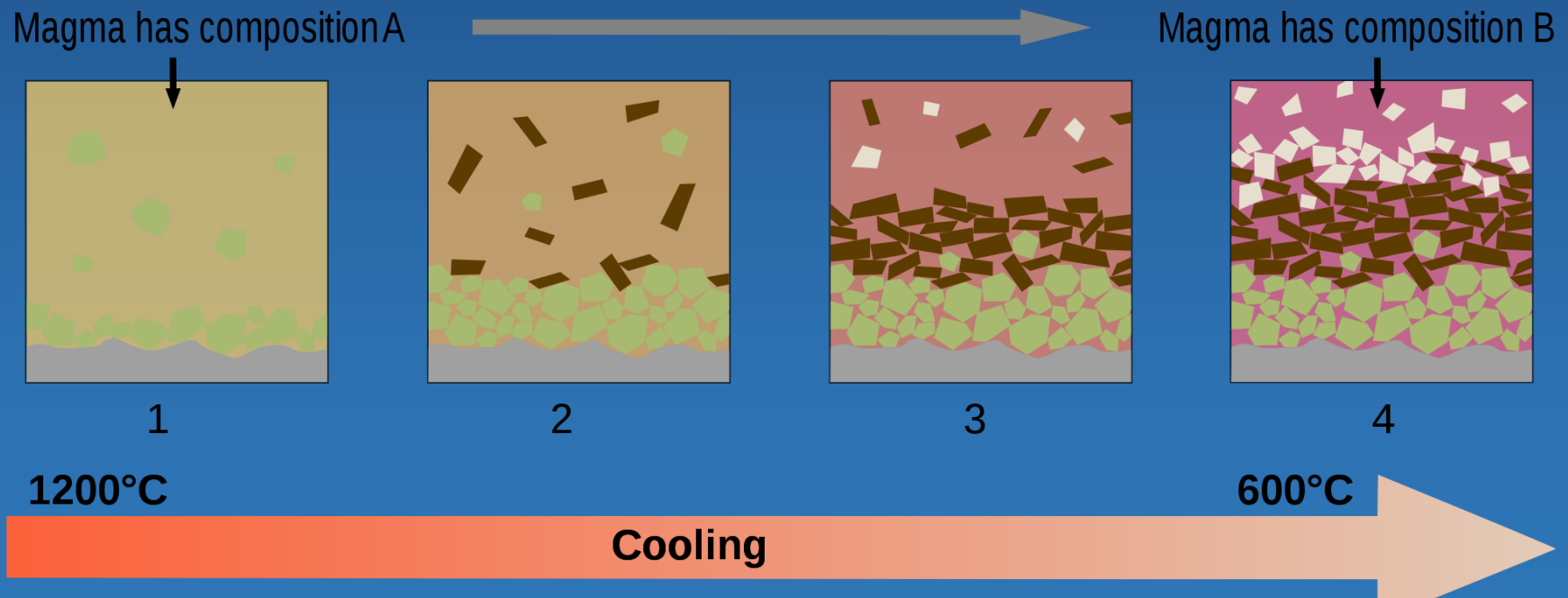
- Addition of elements and minerals from the surrounding rocks



http://jan.ucc.nau.edu/~nrr/GLG100-101/outlines/igneousI.html

Crystal Fractionation

- Mafic minerals crystallize first
- More dense crystals fall out, leaving a more silica-rich magma



Volcanoes

- Structure in the Earth's crust with an opening at the end of central vent or pipe through which magma rises
  - **Active volcano**
    - currently erupting or showing signs of unrest, such as
    - if it has erupted in historic time.
  - **Extinct volcano**
    - Those that scientists consider unlikely to erupt again.
    - Whether a volcano is truly extinct is often difficult to determine.

Central vent eruption

https://en.wikipedia.org/wiki/Mount_St._Helens

http://volcano.oregonstate.edu/oldroot/volcanoes/volc_images/img_paricutin.html

Fissure eruptions

Active fissure

Non-active fissure

Spatter rampart

Where volcanoes occur

- Divergent Margin

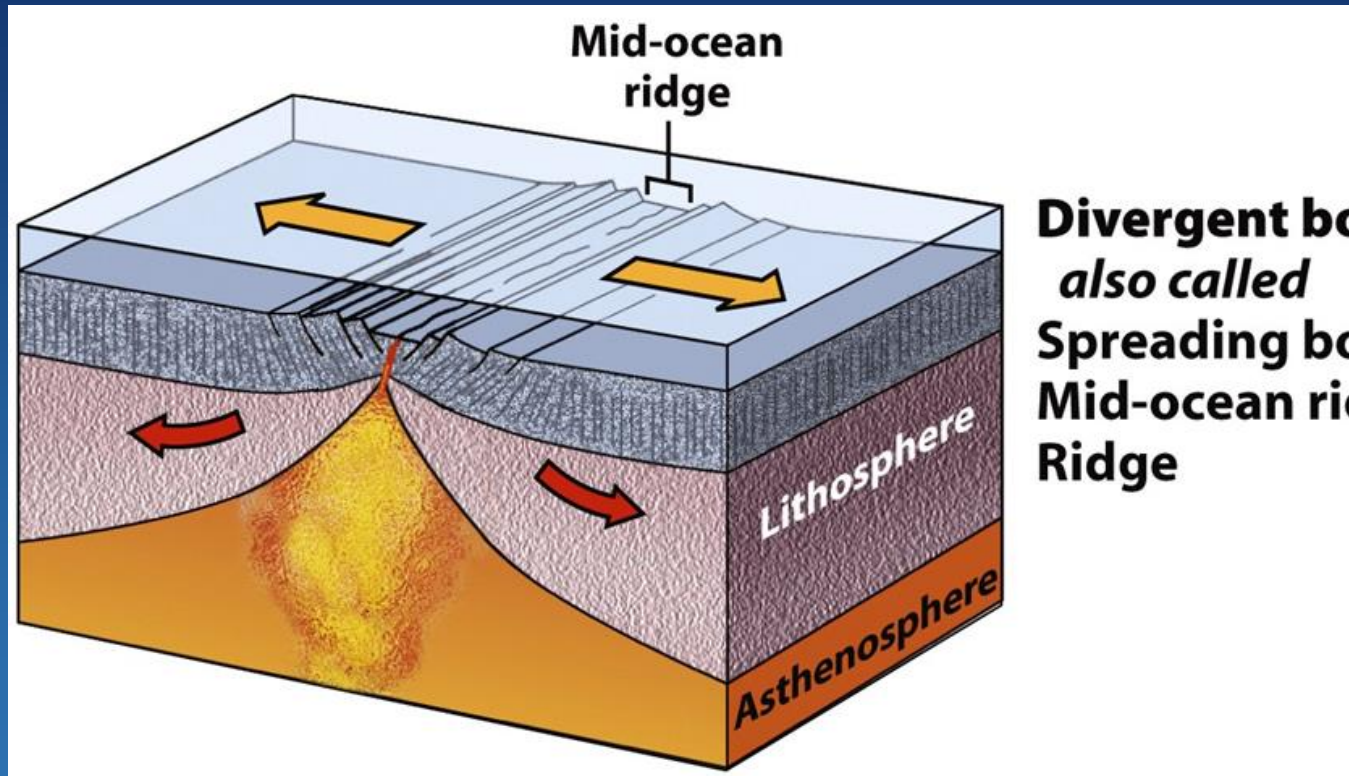
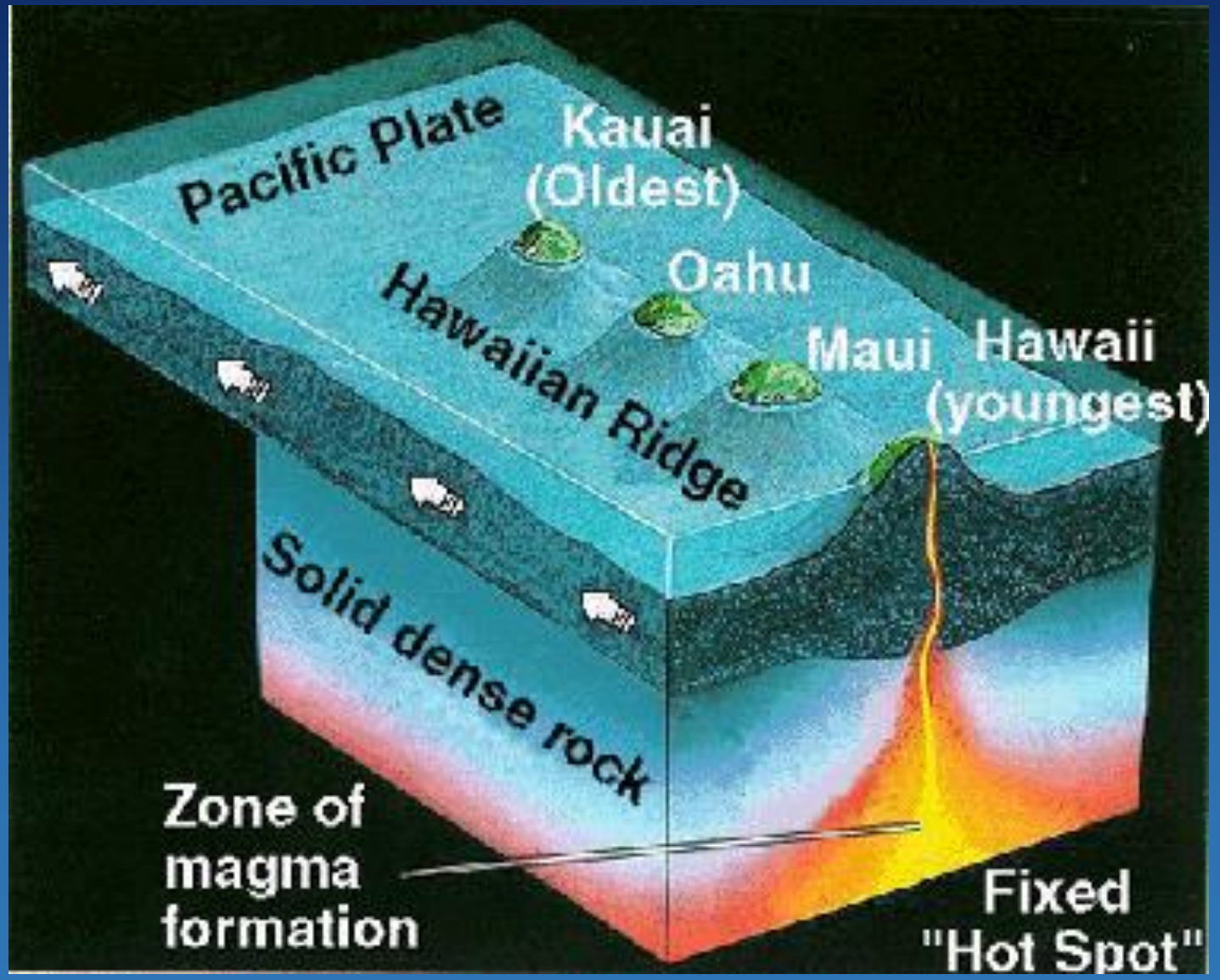


Figure 4-6a Earth: Portrait of a Planet 3/e

Where volcanoes occur

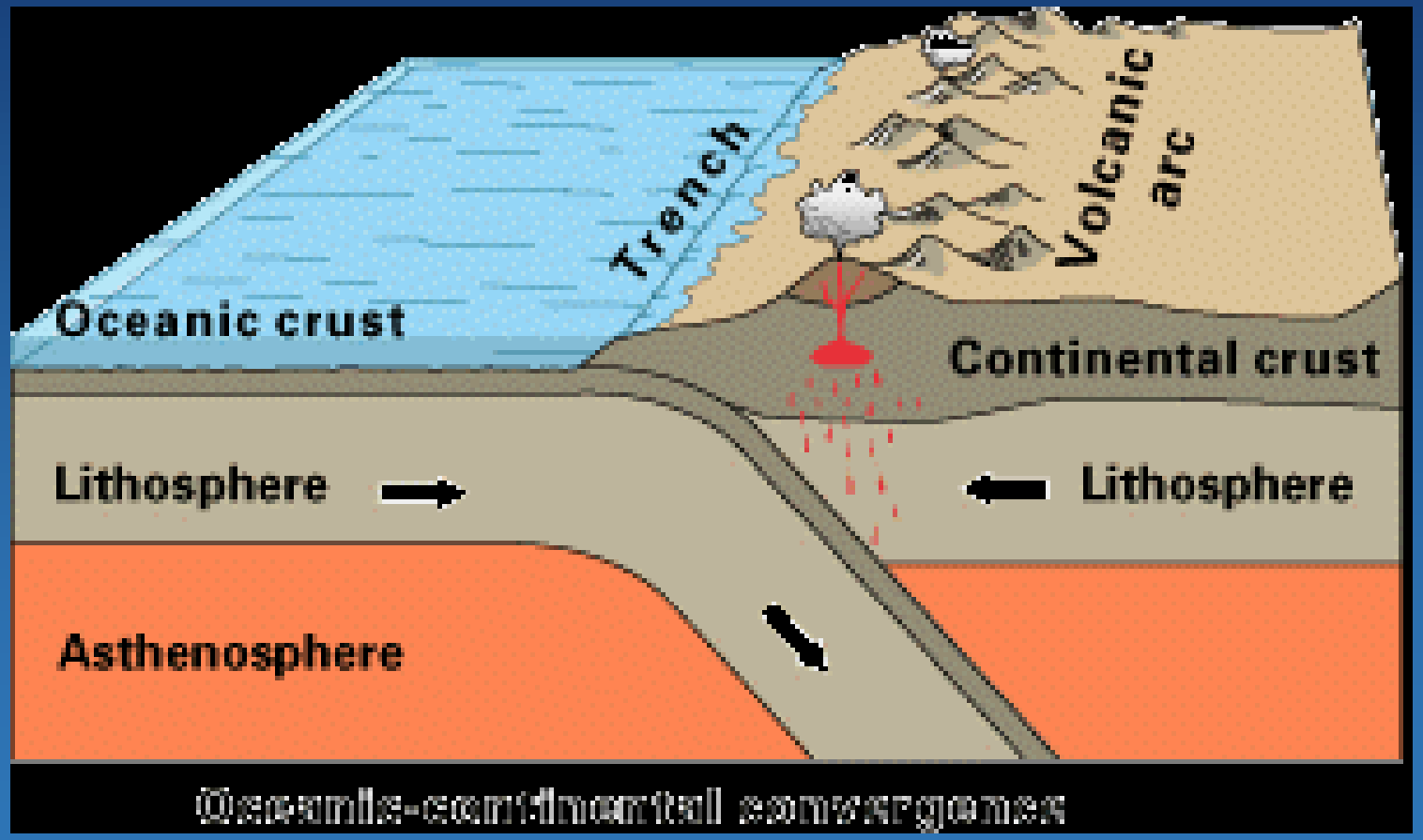
- Mantle Plumes



volcano.oregonstate.edu

Where volcanoes form

- Subduction zones



pubs.usgs.gov

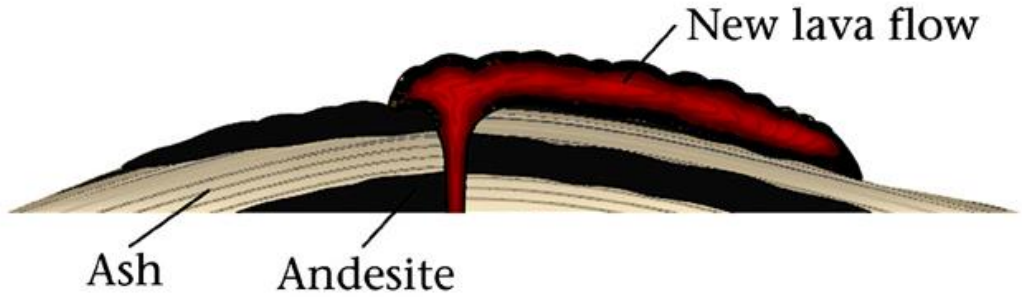
Effusive vs. Explosive

- **Effusive**
- Outpouring of low viscosity magma
- Enormous volumes of lava
- On seafloor and places like Hawaii
- Flow directly from the asthenosphere and upper mantle

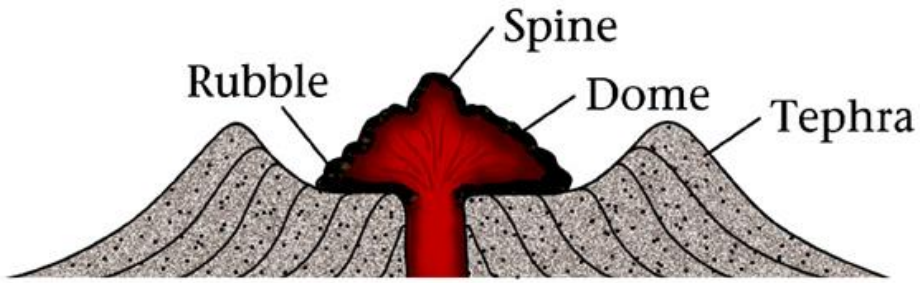
- **Explosive**
- Violent explosions of magma, gas and pyroclastics driven by the buildup pressure in a magma conduit

Effusive vs. Explosive

(a)



(b)



Rhyolitic dome

(c)

FIGURE 9.2

Magma Properties

- Composition
  - How much silica is in the melt? (Si-O bonds)
  - Rock types
    - **Basalt**: Most common volcanic rock (45-52% silica)
    - **Andesite**: (52-63% silica)
    - **Rhyolite** (>68% silica)

Magma Properties

- Viscosity
  - How resistant to flow is the melt?
- Silica-rich lava is more resistant to flow
- Rock types:
  - **Basalt**: low viscosity, can flow 10s km from the vent
  - **Rhyolite**: high viscosity, move slowly

Magma Properties

- Volatile content
  - How much water, carbon dioxide, etc. are in the melt?

- Generally increases with silica content
  - **Basalt**: <1% volatiles by weight
  - **Rhyolite and andesite**: 2-5% volatiles by weight

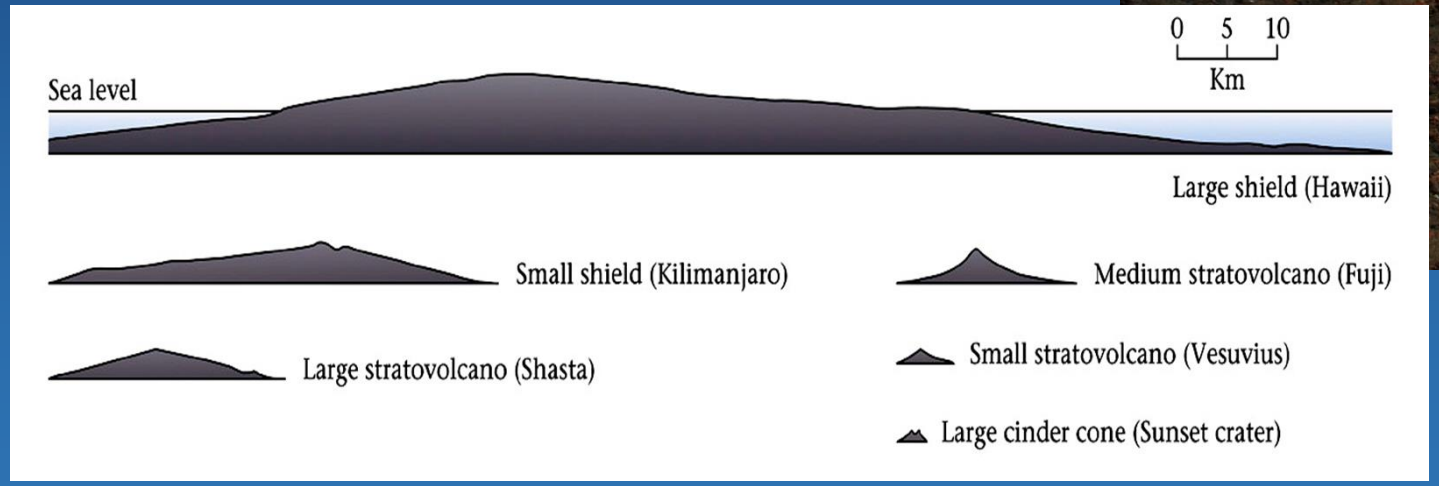
- High volatile content are more likely to be explosive (dissolved volatiles are released from the magma during decompression)

Volcano Types

- Flood Basalts
- Shield volcano
- Composite (Stratovolcano)
- Cinder Cones

Shield Volcano

- Largest on Earth
- Gently sloping sides
- Basaltic magma



https://upload.wikimedia.org/wikipedia/commons/0/0f/Mauna_Kea_from_Mauna_Loa_Observatory%2C_Hawaii_-_20100913.jpg

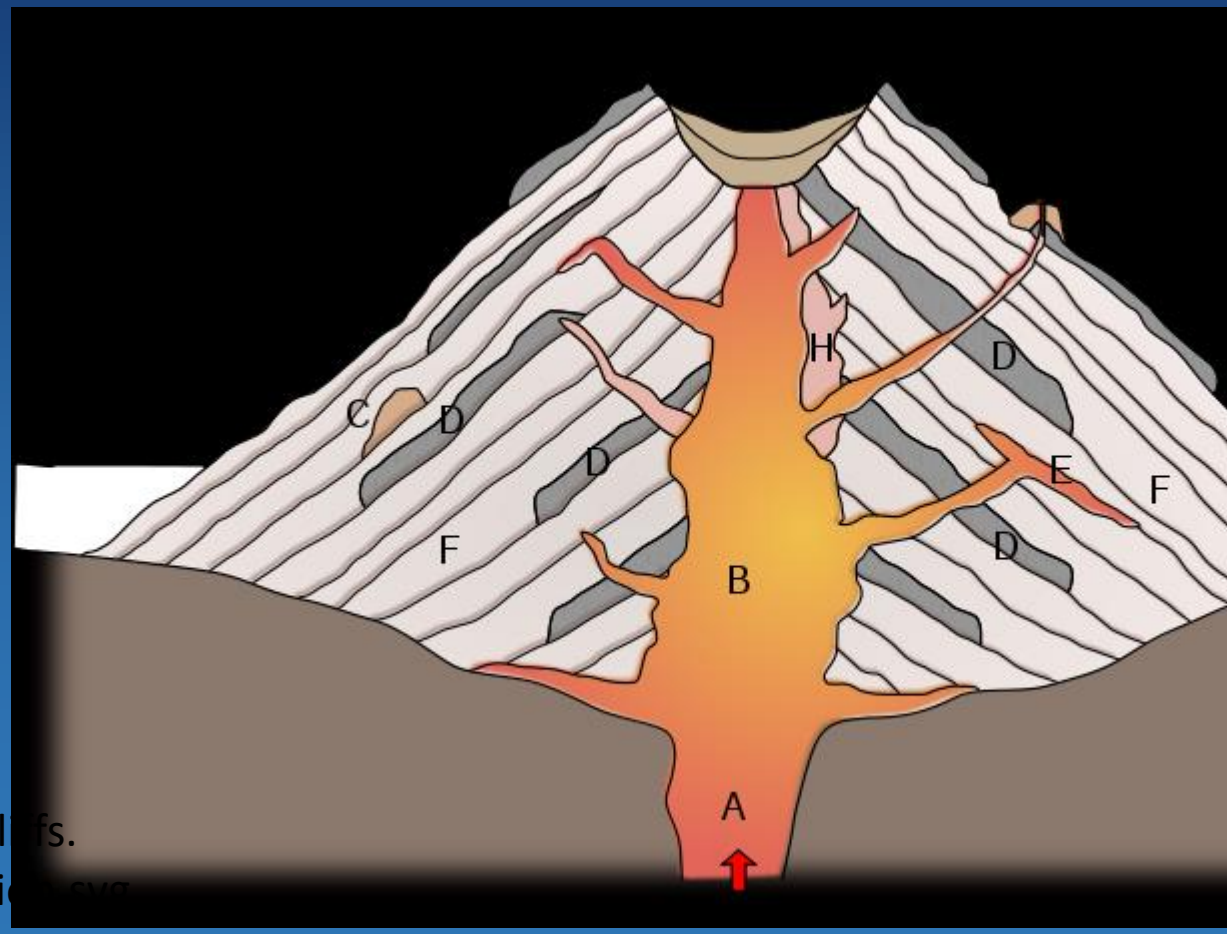
Composite Volcano

- Stratovolcano volcanoes
- Erupt less frequently than shield

http://www.britannica.com/place/Mount-Fuji

Composite Volcano

- Interlayered lavas and pyroclastic deposits
- Lava relatively silica-rich
- eg. Mt. St. Helens, Vesuvius

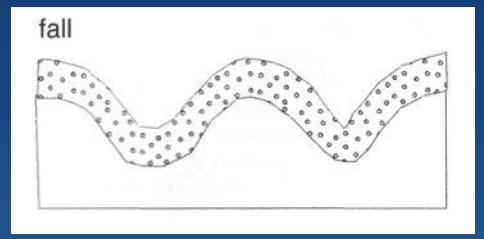


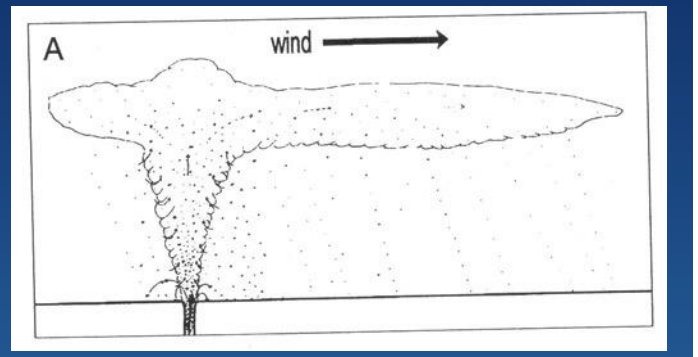
Macdonald, G.A.; 1972: Volcanoes, Prentice-Hall, Inc., Englewood Cl fs.
https://commons.wikimedia.org/wiki/File:Stratovolcano_cross-secti svg

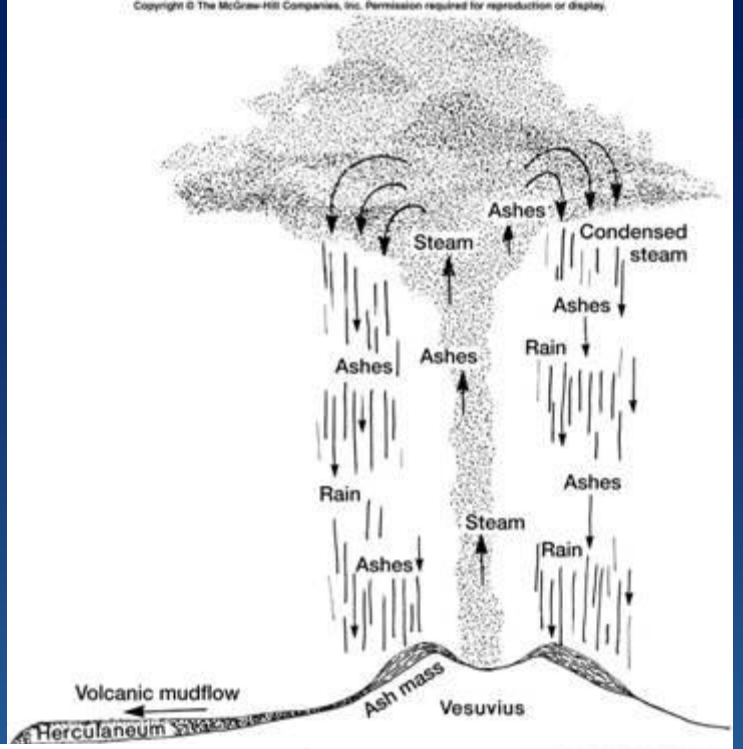
Pyroclastic Flows

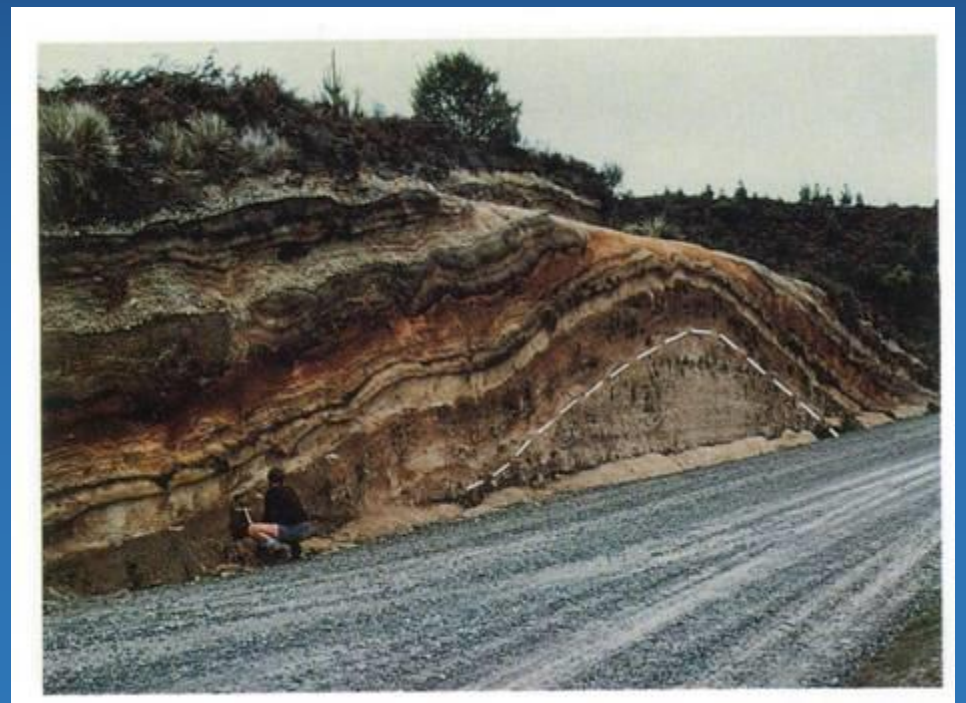
- Hot gas and rock (tephra)
- Gas is superheated
- Move fast (up to 700km/hr)
- (Due to gravity)

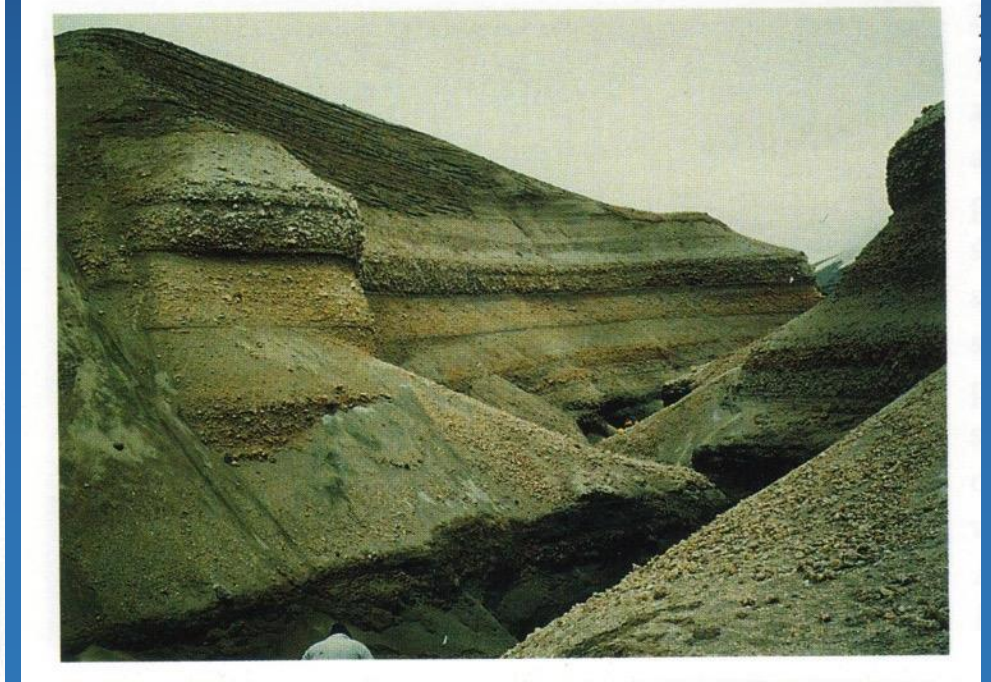
Pyroclastic fall deposits



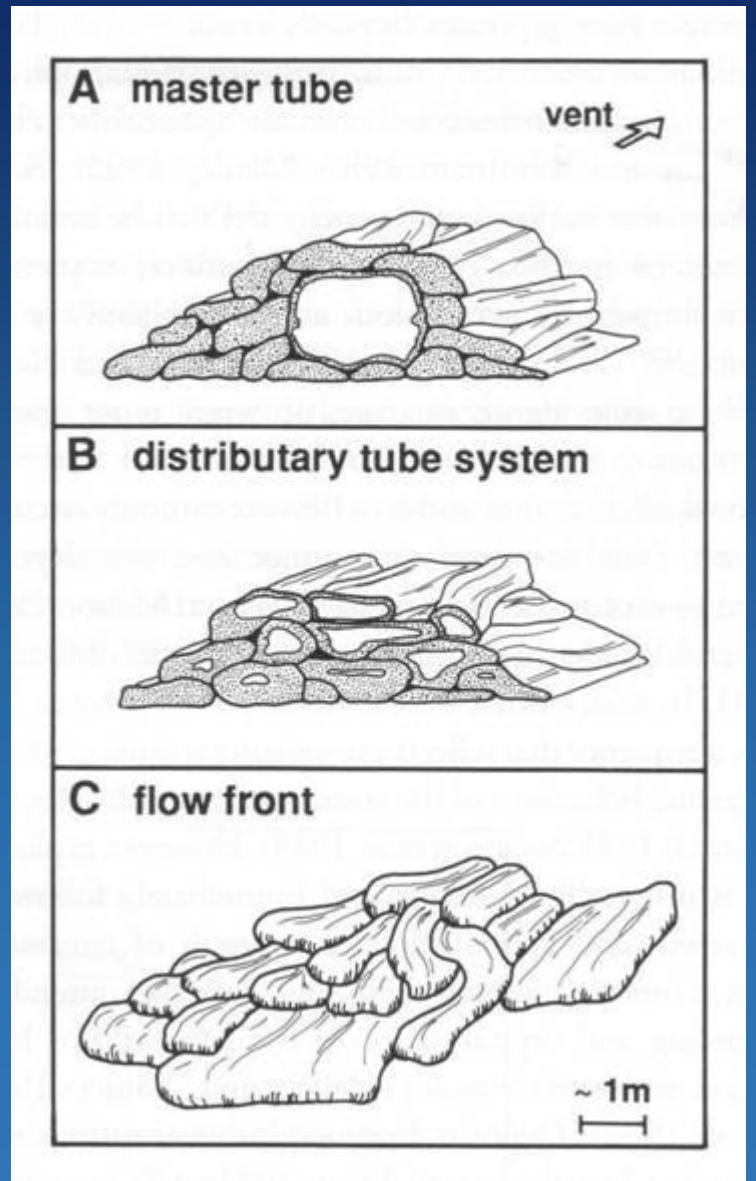




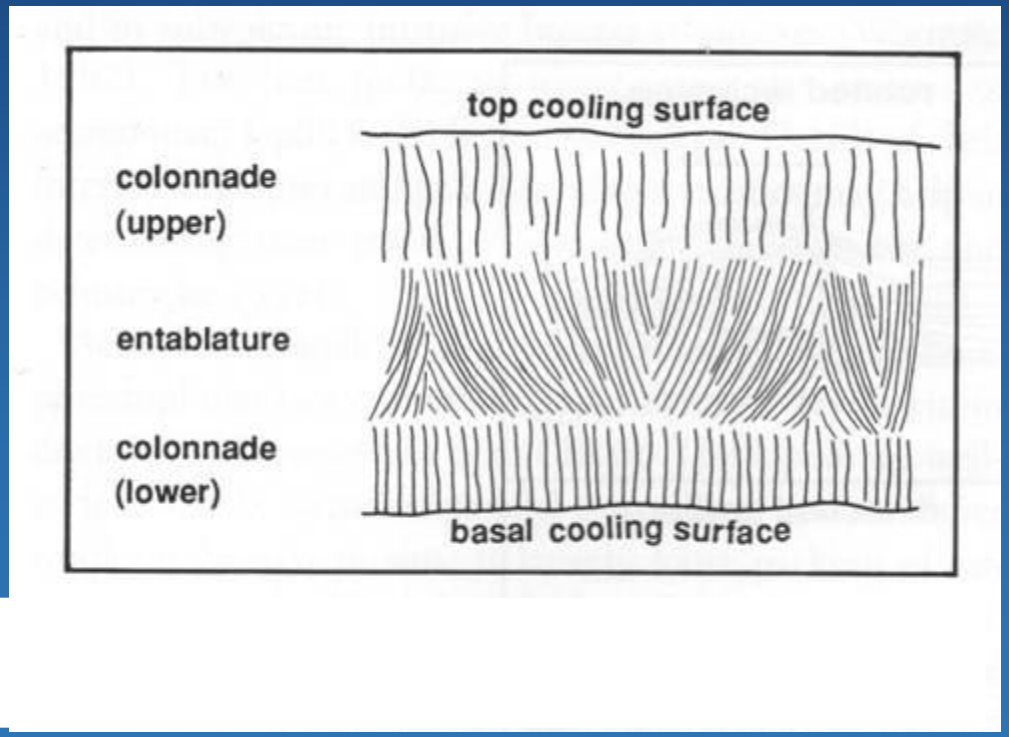


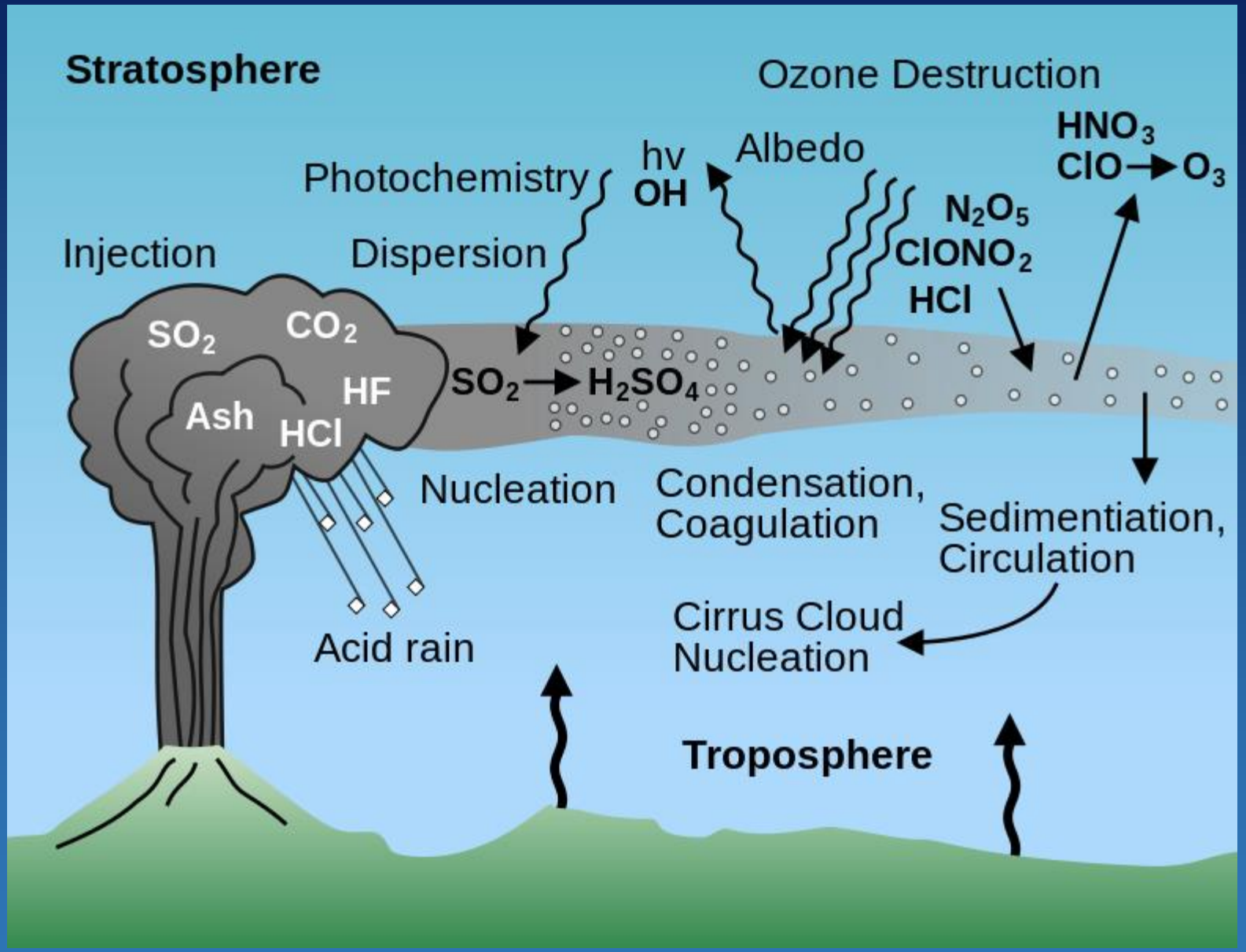


Basalt: Pillow formation

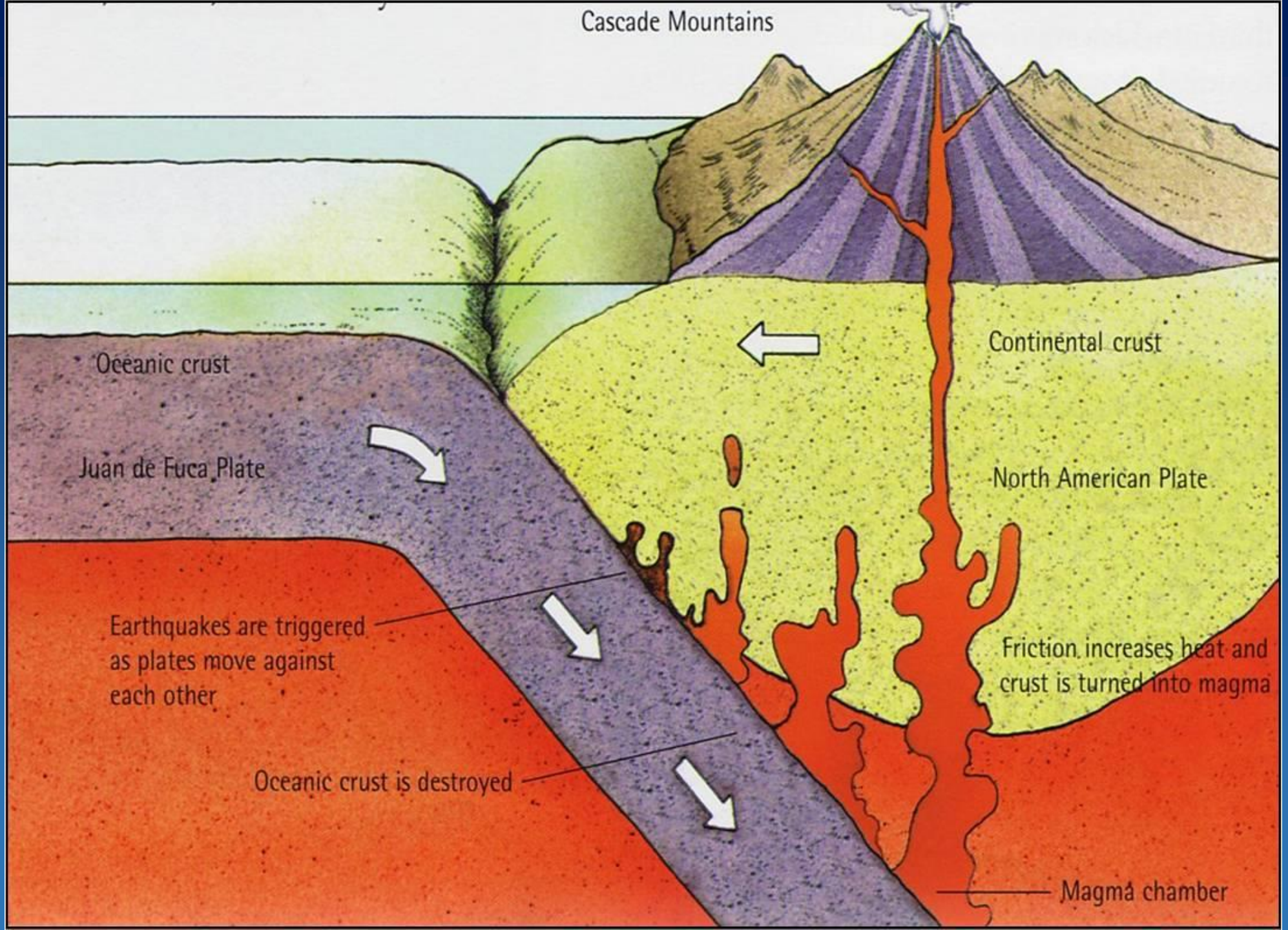


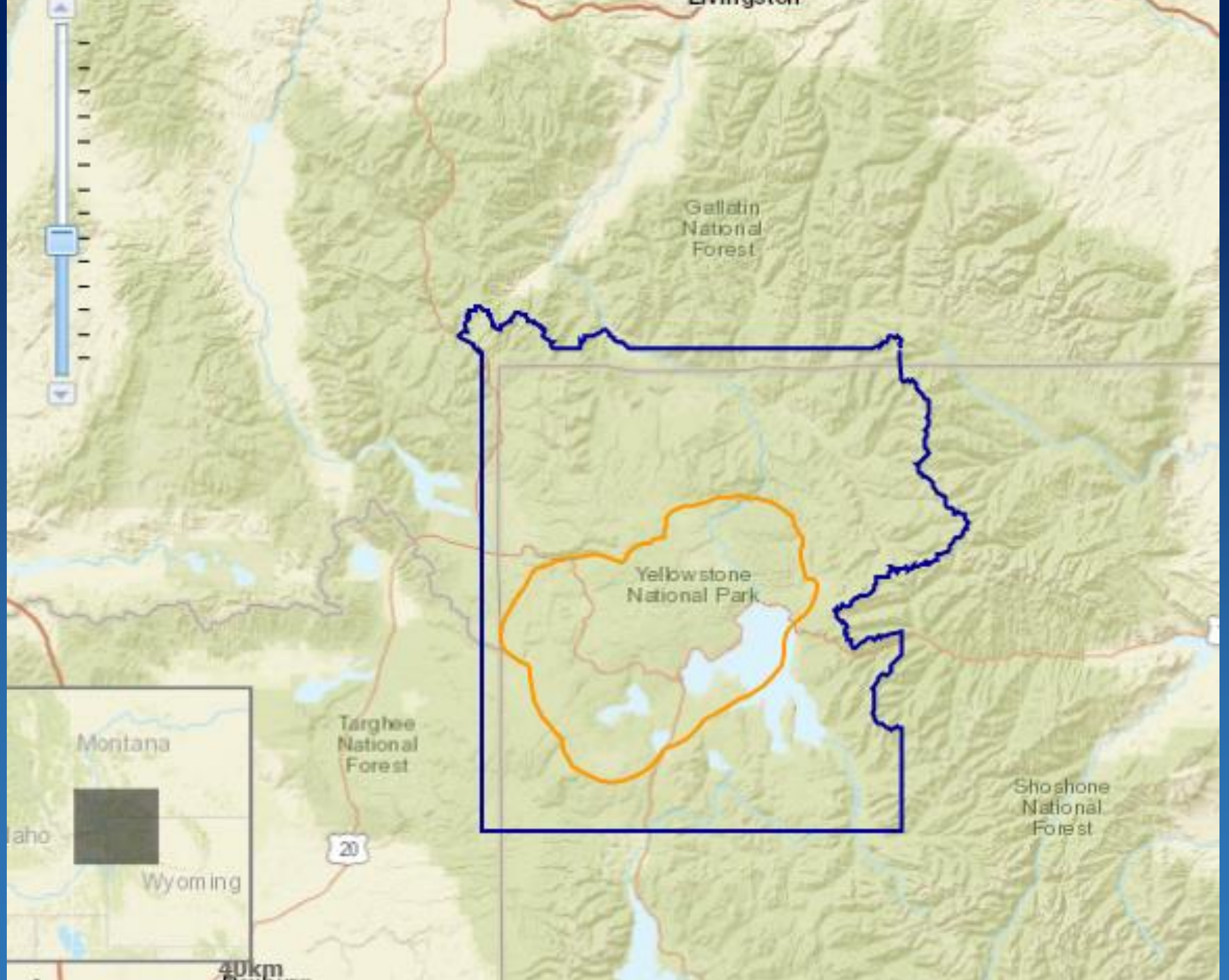
Massive lava jointing

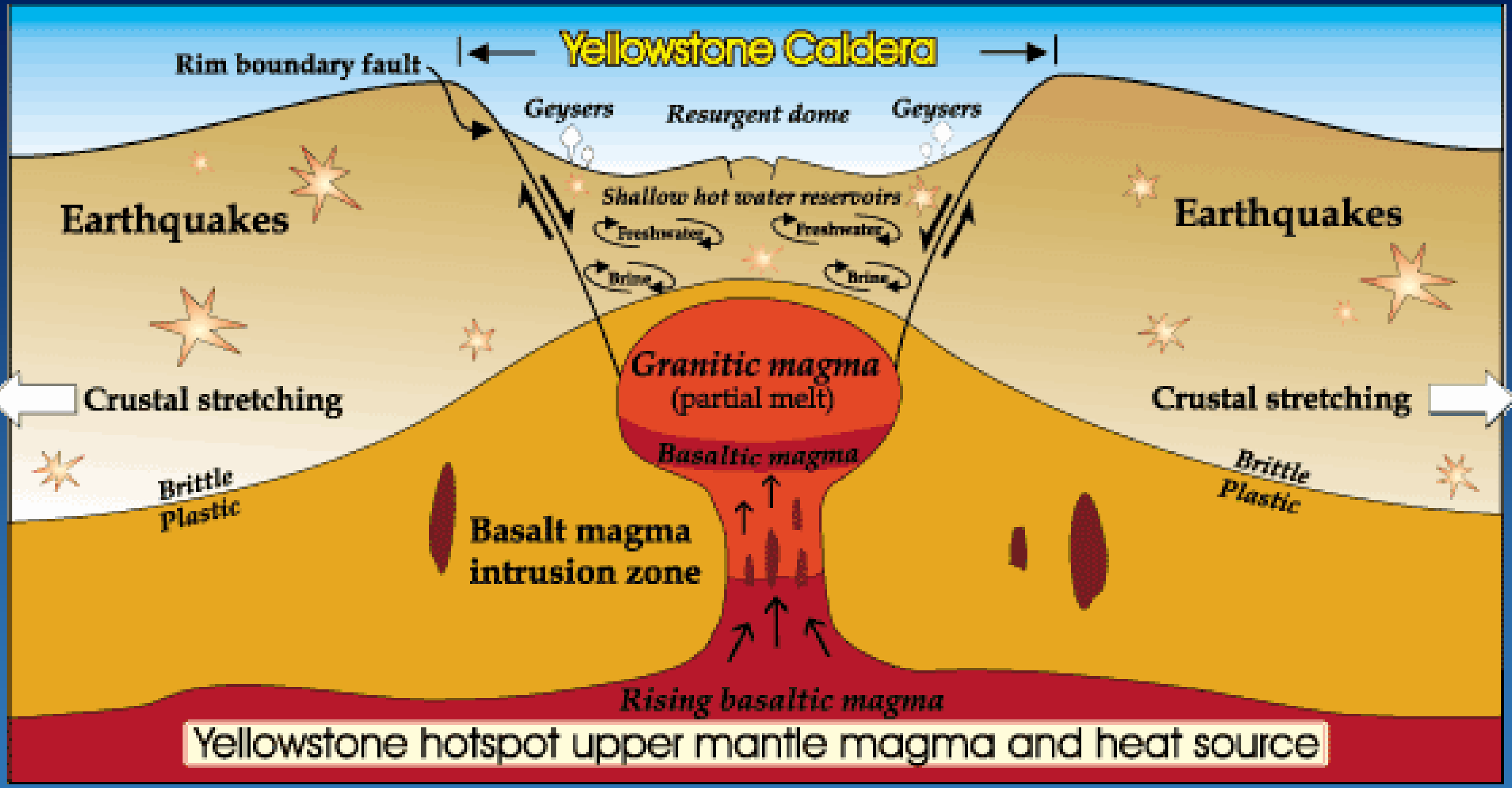


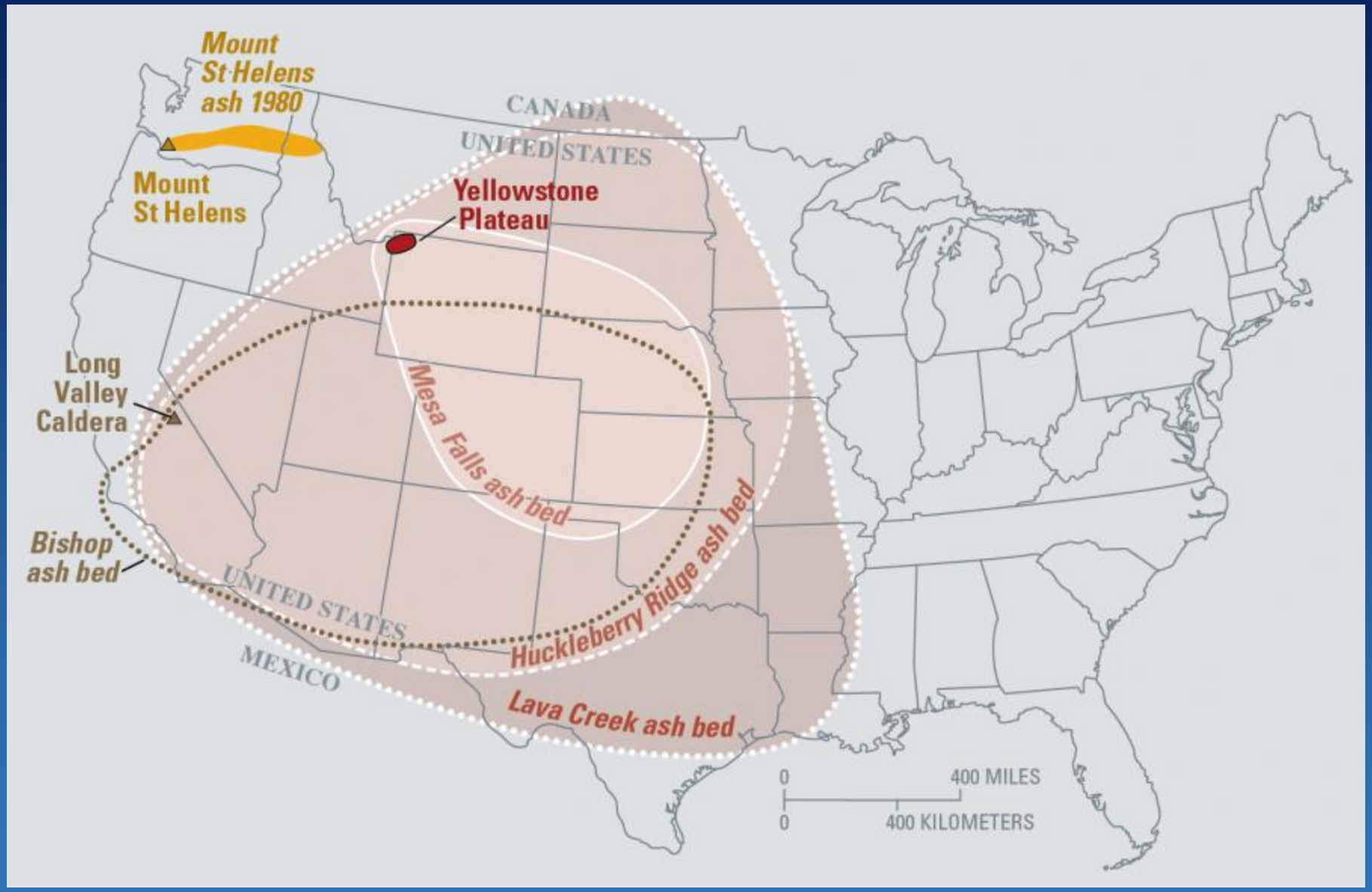

Stratosphere
Ozone Destruction
HNO_3
ClO → O_3
hv
OH
Albedo
Photochemistry
N_2O_5
$ClONO_2$
HCl
Injection
Dispersion
SO_2
CO_2
HF
Ash
HCl
SO_2 → H_2SO_4
Nucleation
Condensation,
Coagulation
Sedimentiation,
Circulation
Acid rain
Cirrus Cloud
Nucleation
Troposphere

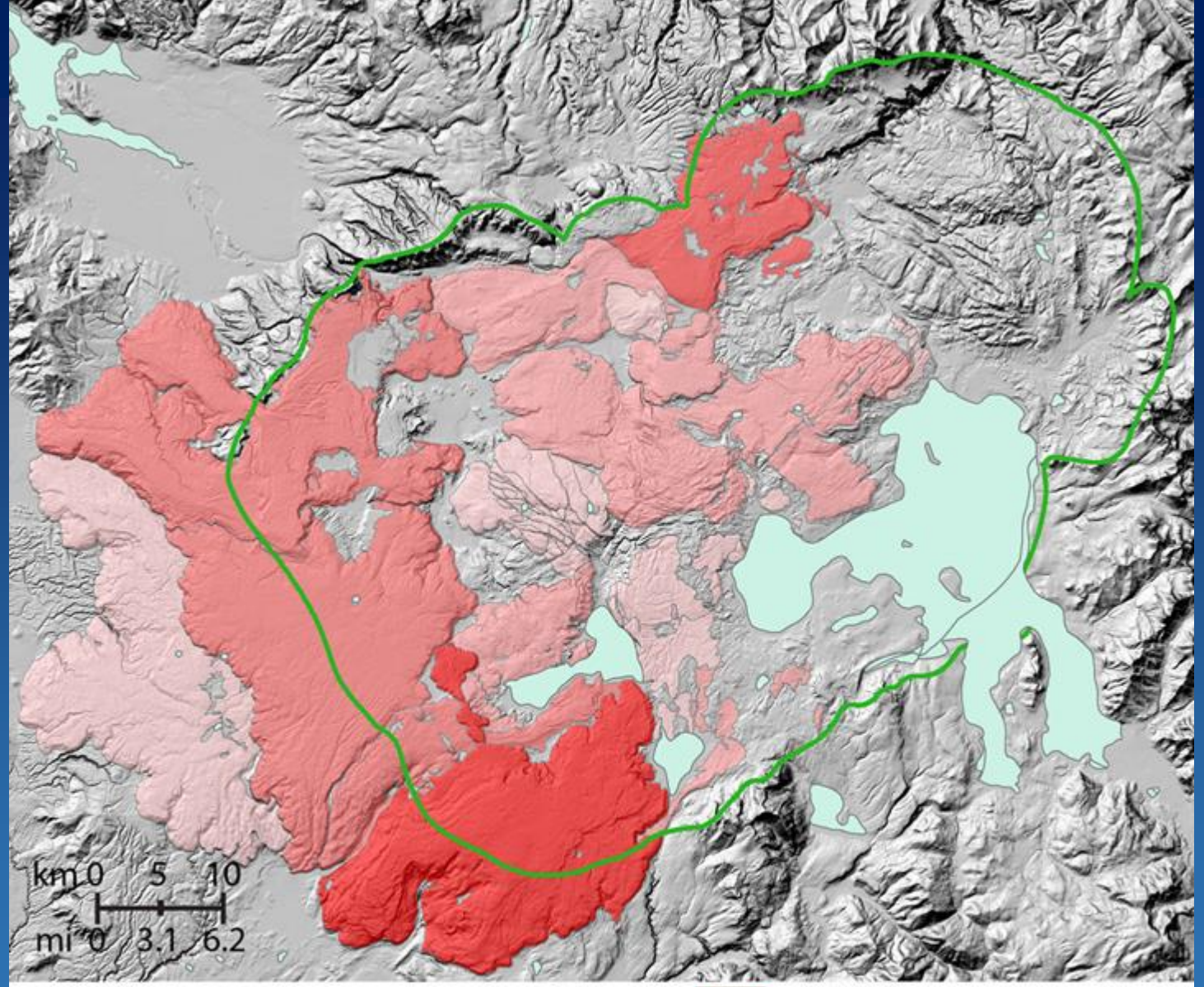
USGS


Cascade Mountains
Oceanic crust
Juan de Fuca Plate
Continental crust
North American Plate
Earthquakes are triggered as plates move against each other
Friction increases heat and crust is turned into magma
Oceanic crust is destroyed
Magma chamber


Gallatin
National
Forest
Yellowstone
National Park
Targhee
National
Forest
Shoshone
National
Forest
20
Montana
Wyoming
40km


Yellowstone Caldera
Rim boundary fault
Geysers
Resurgent dome
Geysers
Shallow hot water reservoirs
Freshwater
Freshwater
Brine
Brine
Earthquakes
Earthquakes
Granitic magma
(partial melt)
Basaltic magma
Crustal stretching
Crustal stretching
Brittle
Plastic
Brittle
Plastic
Basalt magma
intrusion zone
Rising basaltic magma
Yellowstone hotspot upper mantle magma and heat source


Mount St Helens ash 1980
Mount St Helens
CANADA
UNITED STATES
Yellowstone Plateau
Long Valley Caldera
Mesa Falls ash bed
Bishop ash bed
Huckleberry Ridge ash bed
UNITED STATES
MEXICO
Lava Creek ash bed
0
400 MILES
0
400 KILOMETERS



Yellowstone Lava Flows

lake

caldera boundary

~72 thousand years

~102-114 thousand years

~152 thousand years

~164 thousand years