Volcanoes

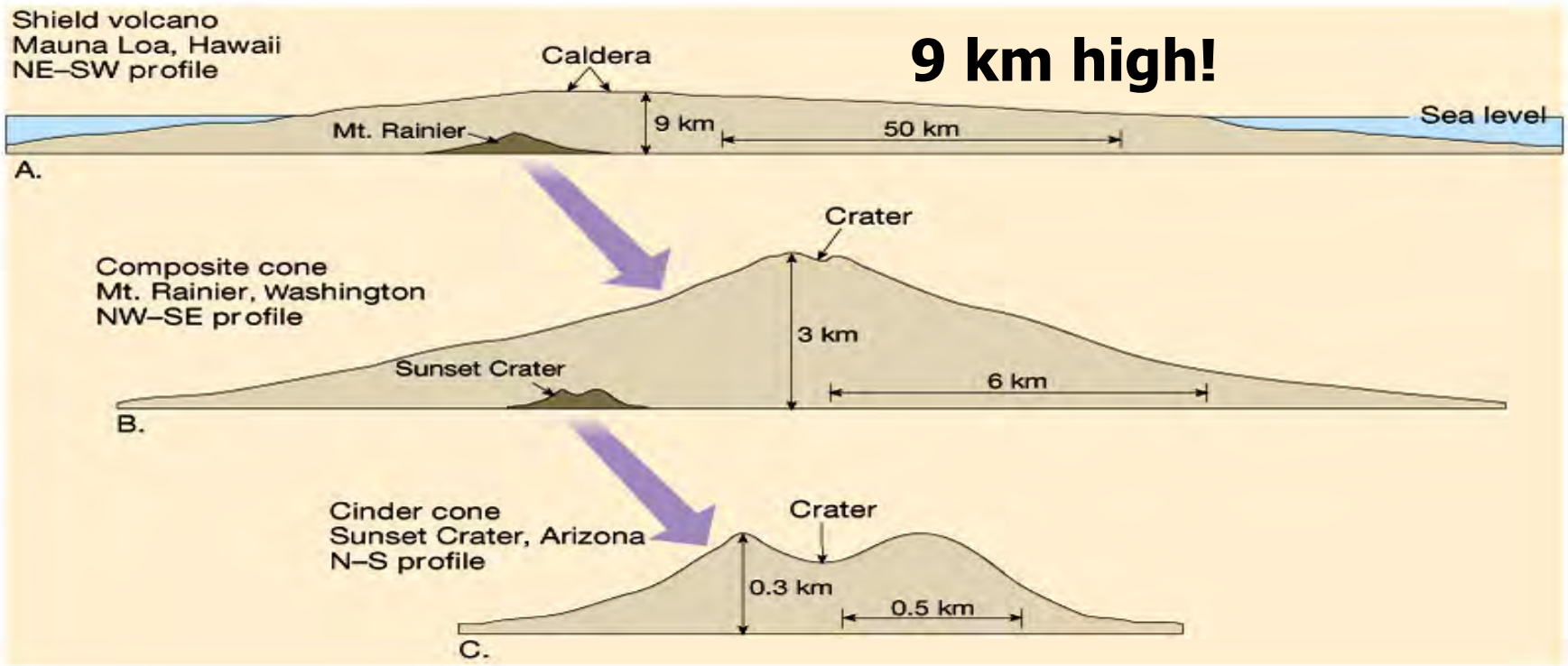
D

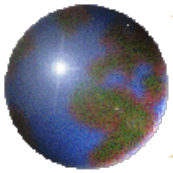
Volcanoes

- Name the largest volcano on Earth
- Name the tallest mountain on Earth, measured from top to bottom
- Visualize your expectations of what this mountain should look like

Mauna Loa

A size comparison of the three types of volcanoes

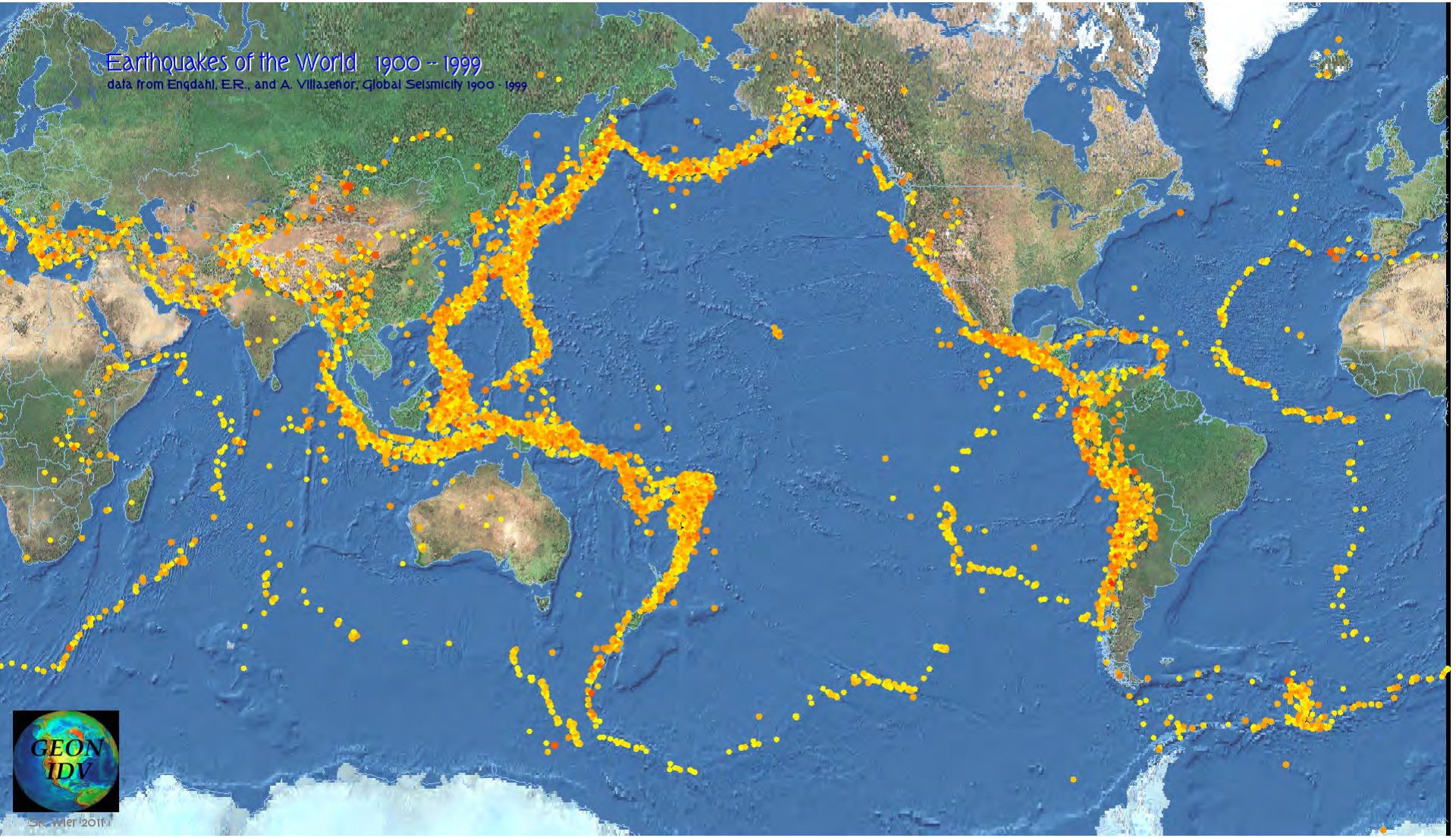


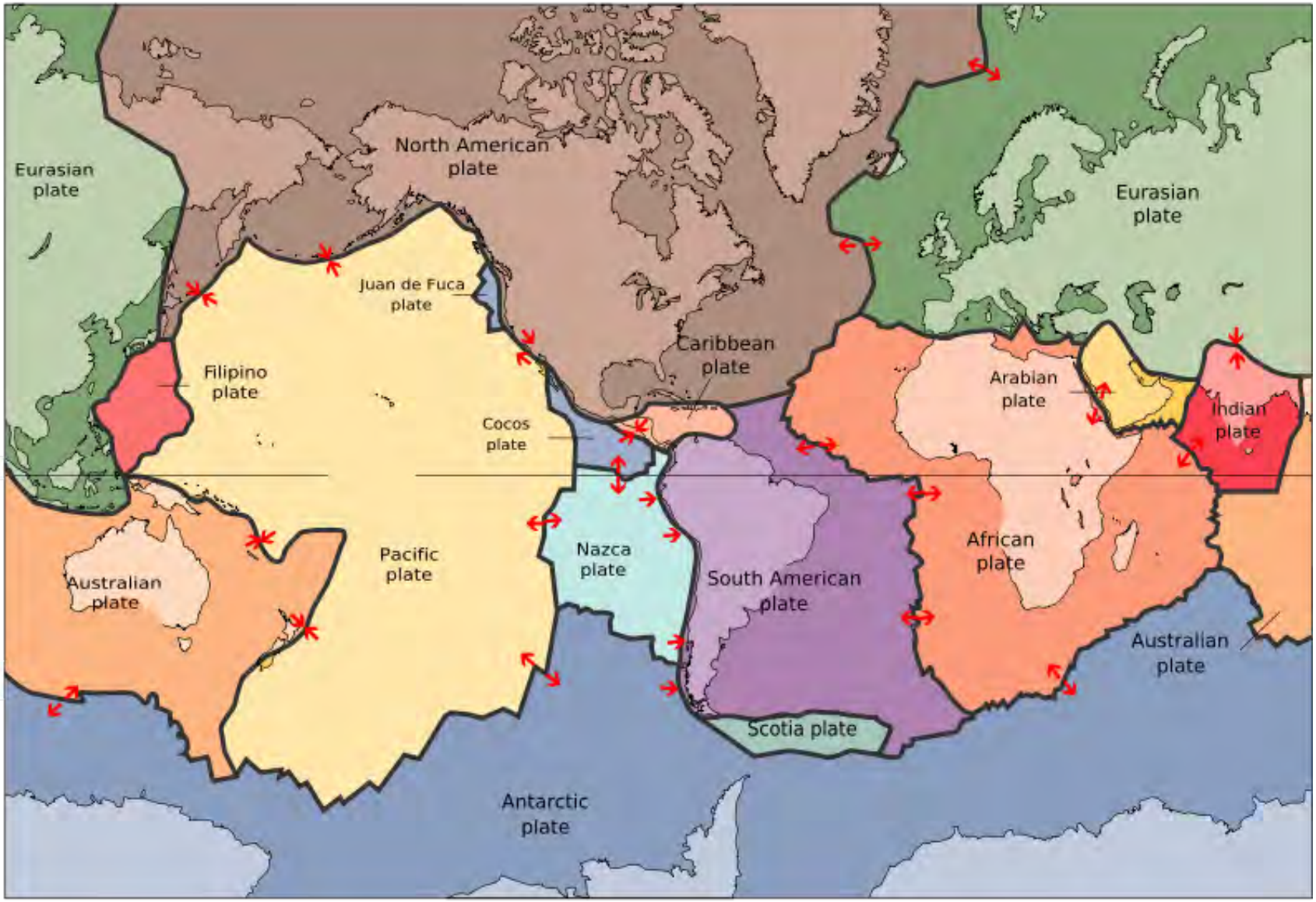


Igneous activity & plate tectonics

- **Global distribution of igneous activity is not random**
  - Most volcanoes are located within or near ocean basins
  - Basaltic rocks are common in both oceanic and continental settings; granitic rocks are rarely found in the oceans
  - Ocean crust (mafic) = (modified) mantle

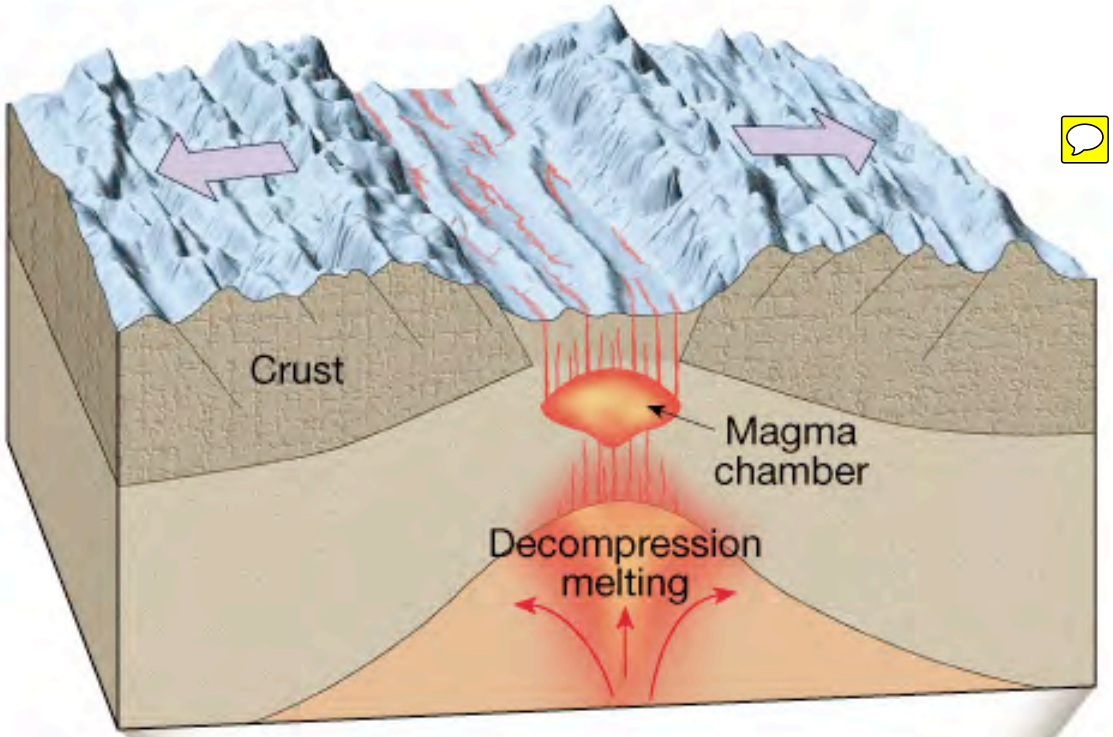
Distribution of some major volcanoes


Earthquakes of the World 1900 - 1999
data from Engdahl, E.R., and A. Villaseñor, Global Seismicity 1900 - 1999
GEON IDV

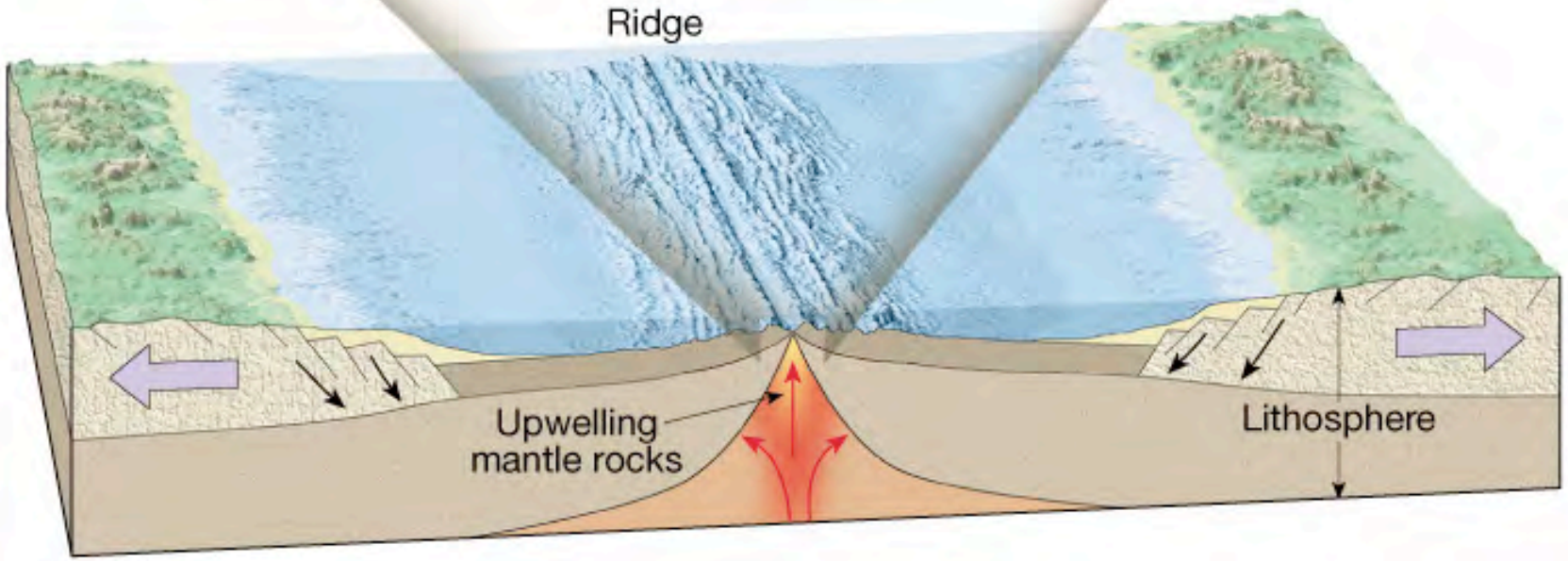

Eurasian plate
North American plate
Eurasian plate
Juan de Fuca plate
Caribbean plate
Filipino plate
Arabian plate
Indian plate
Cocos plate
Pacific plate
Nazca plate
South American plate
African plate
Australian plate
Australian plate
Scotia plate
Antarctic plate

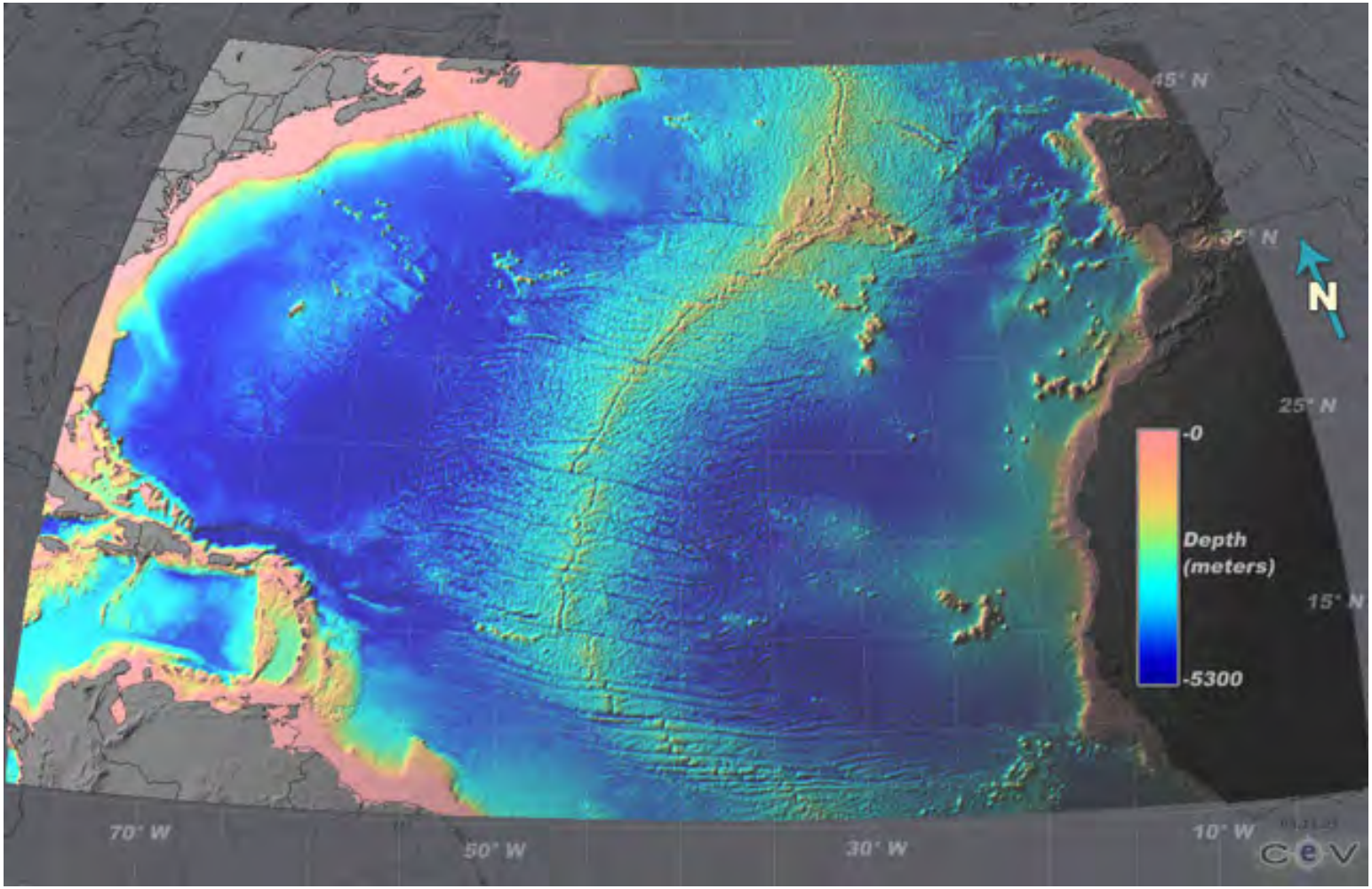
Igneous activity & plate tectonics

- **Igneous activity along plate margins**
  - **1) Spreading centers**
    - Greatest volume of volcanic rock is produced along the oceanic ridge system (divergence)
    - Mechanism of (decompression) melting
      - Lithosphere pulls apart
      - Less pressure on underlying rocks
      - Results in partial melting of mantle
      - Large quantities of basaltic magma are produced



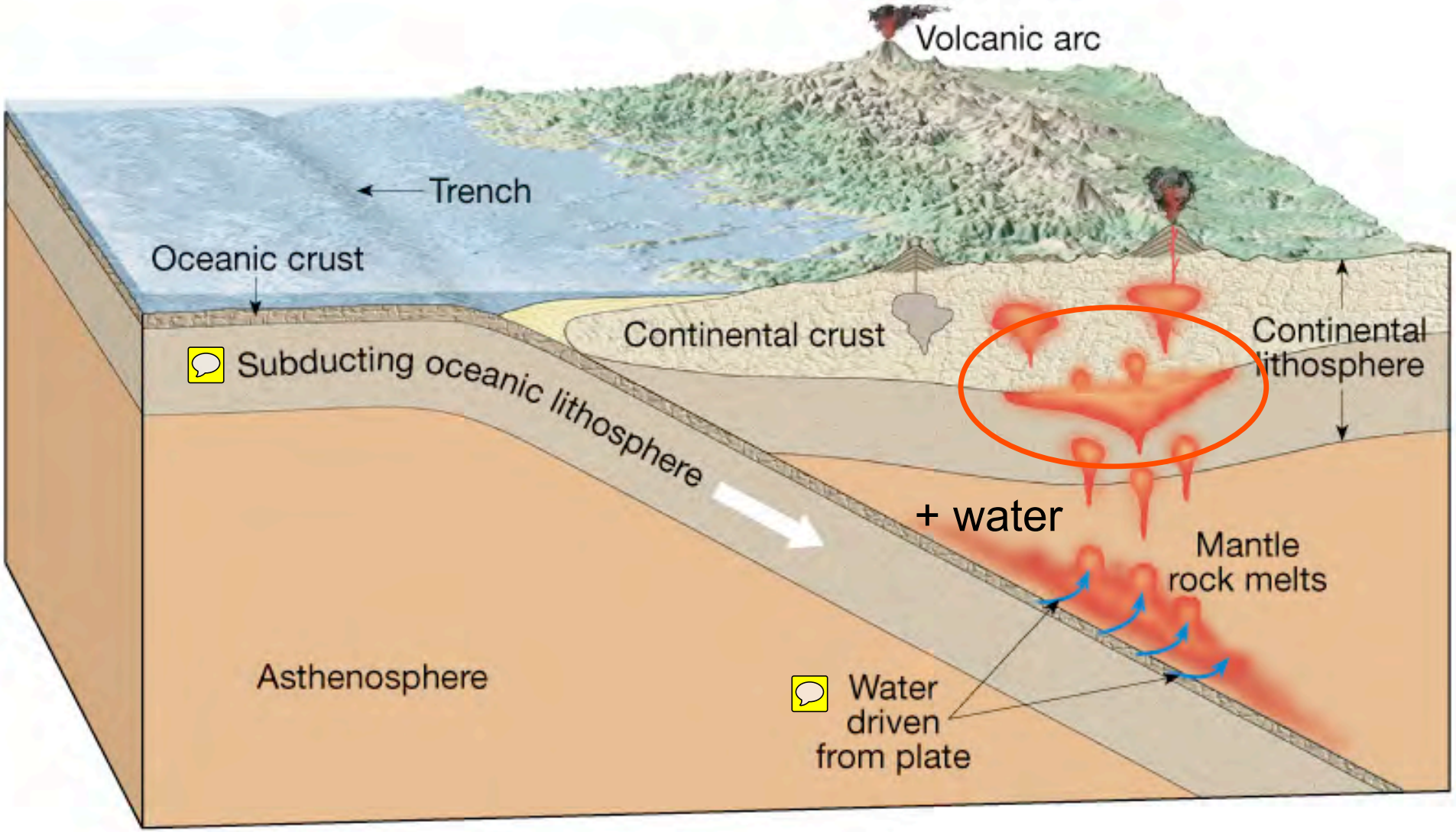
Ocean crust (mafic) = (modified) mantle

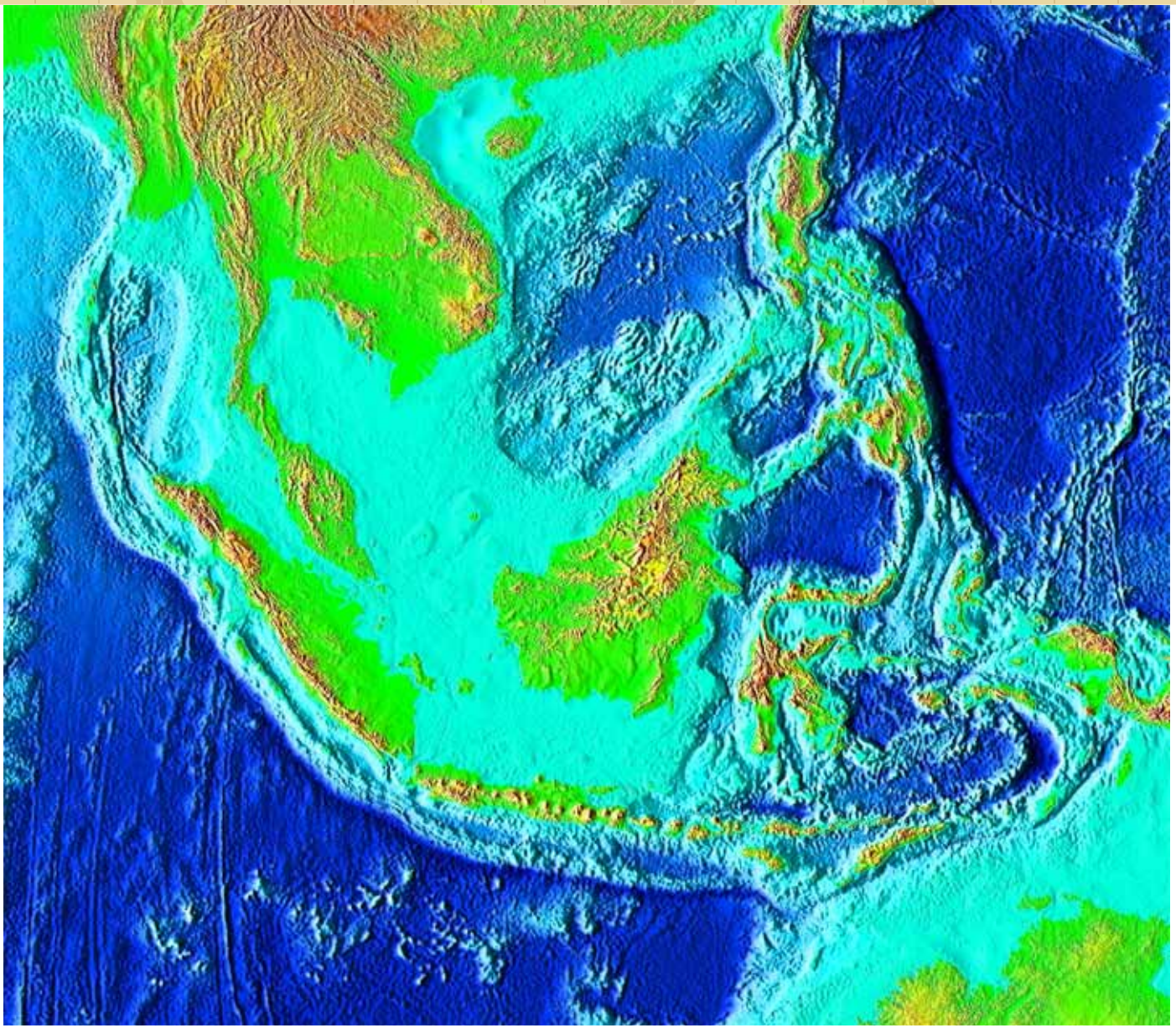



45° N
35° N
25° N
15° N
N
-0
Depth
(meters)
-5300
70° W
50° W
30° W
10° W

Igneous activity & plate tectonics

- **Igneous activity along plate margins**
  - **2) Subduction zones**
    - Occur in conjunction with deep oceanic trenches (convergence)
    - Descending plate partially melts + release H_2O
    - Magma slowly moves upward
    - Rising magma can form either:
      - An island arc if in the ocean
      - A volcanic arc if on a continental margin
      - Both are andesitic (intermediate) composition

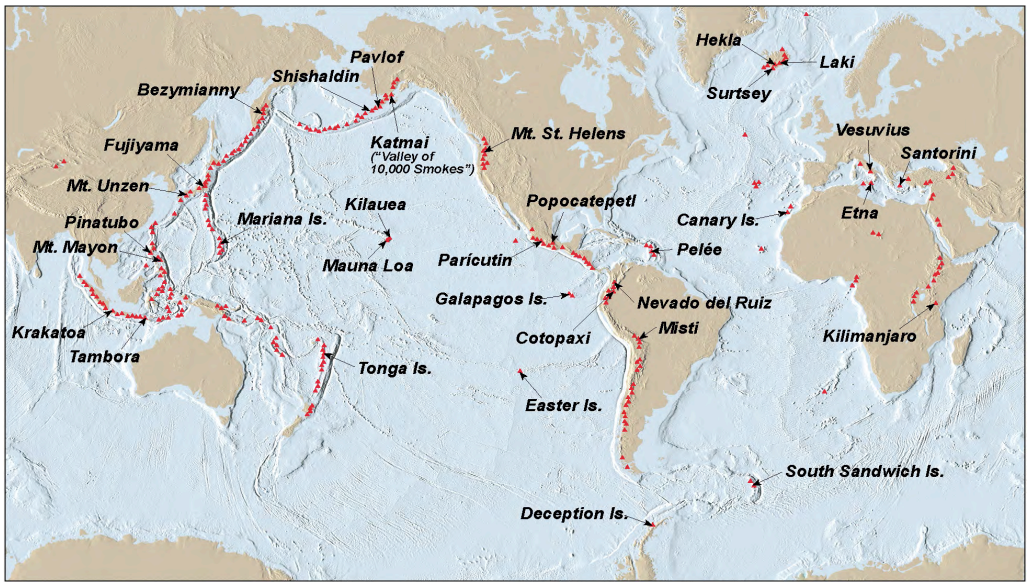

Volcanic arc
Trench
Oceanic crust
Continental crust
Continental lithosphere
Subducting oceanic lithosphere
+ water
Mantle rock melts
Asthenosphere
Water driven from plate



Igneous activity & plate tectonics

2) Subduction zones, cont.

- Associated with the Pacific Ocean Basin
  - Region around the margin is known as the 'Ring of Fire'
  - Most of the world's explosive volcanoes



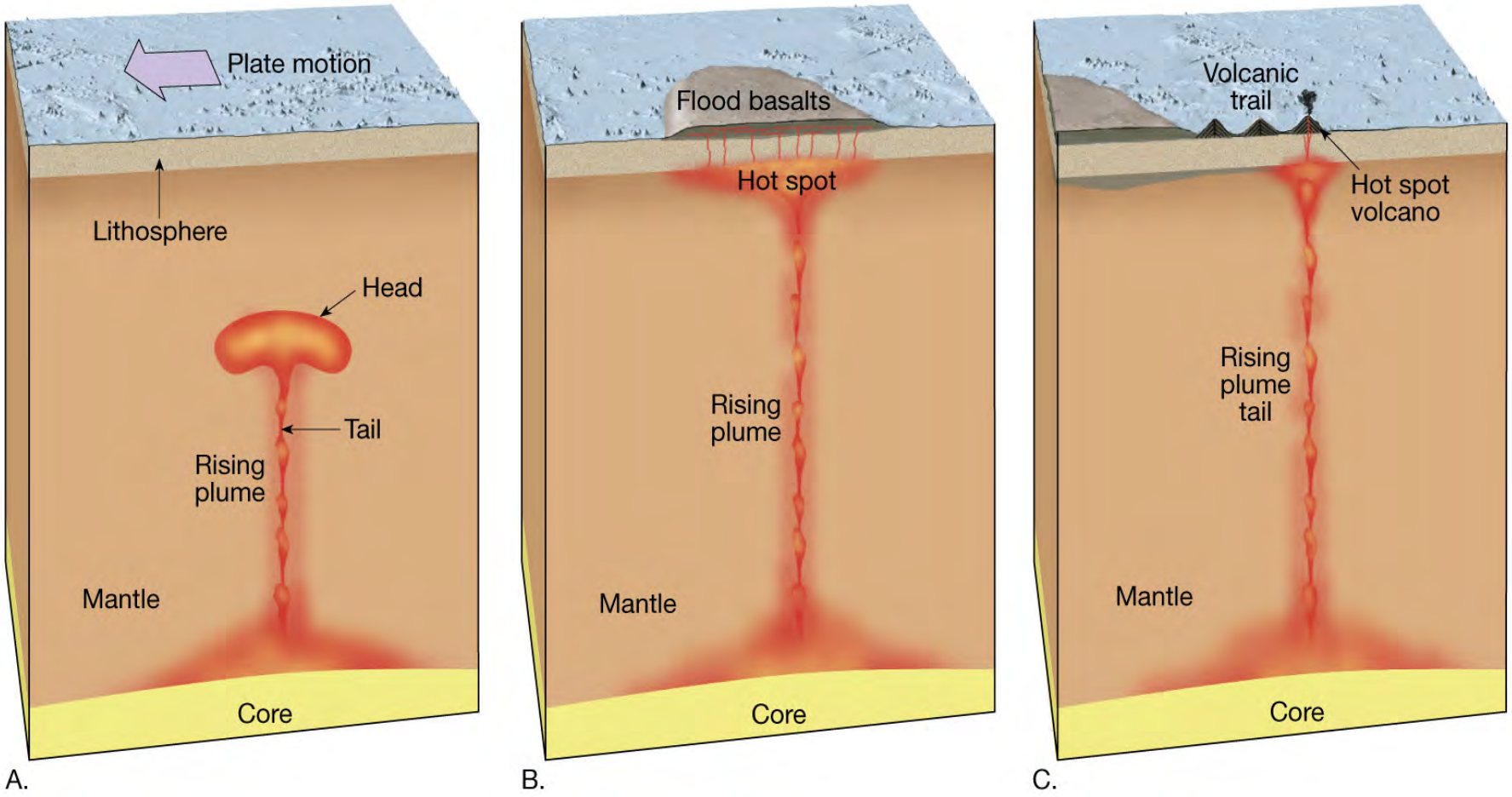
Igneous activity & plate tectonics

- **Intraplate volcanism**
  - Activity within a tectonic plate
  - Associated with plumes of heat in the mantle
  - Form localized volcanic regions in the overriding plate called a hot spot

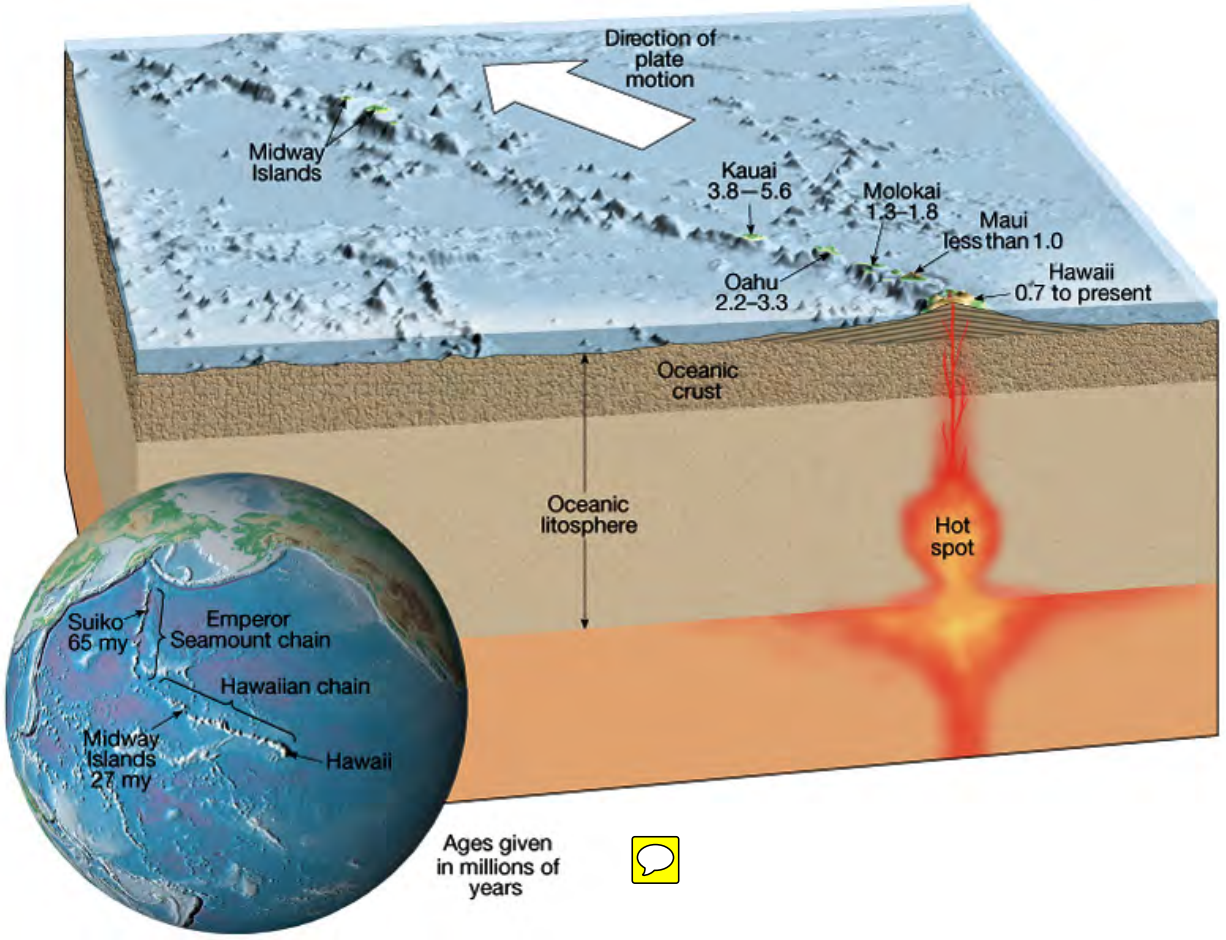
  –Produces basaltic magma sources in oceanic crust (e.g., Hawaii and Iceland)

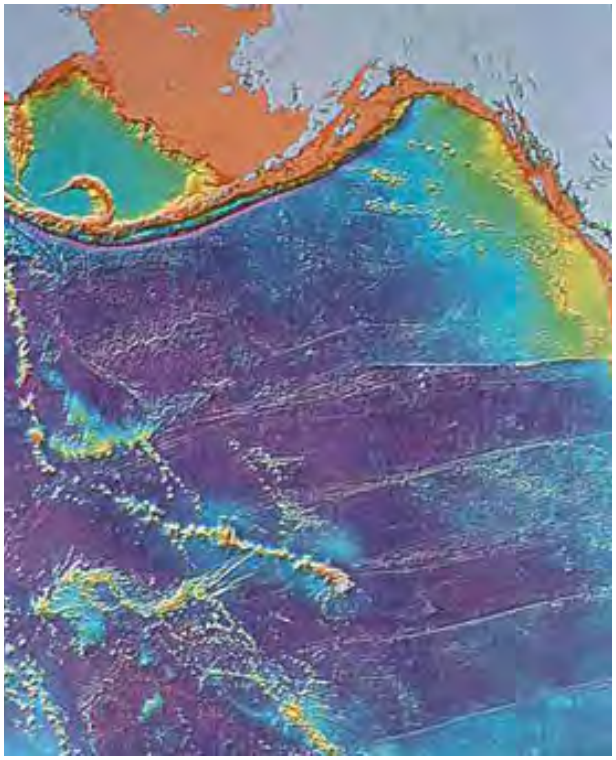
  –Produces granitic magma sources in continental crust (e.g., Yellowstone Park)

Volcanism on a tectonic plate moving over a hot spot



Tectonic plate moving over a hot spot

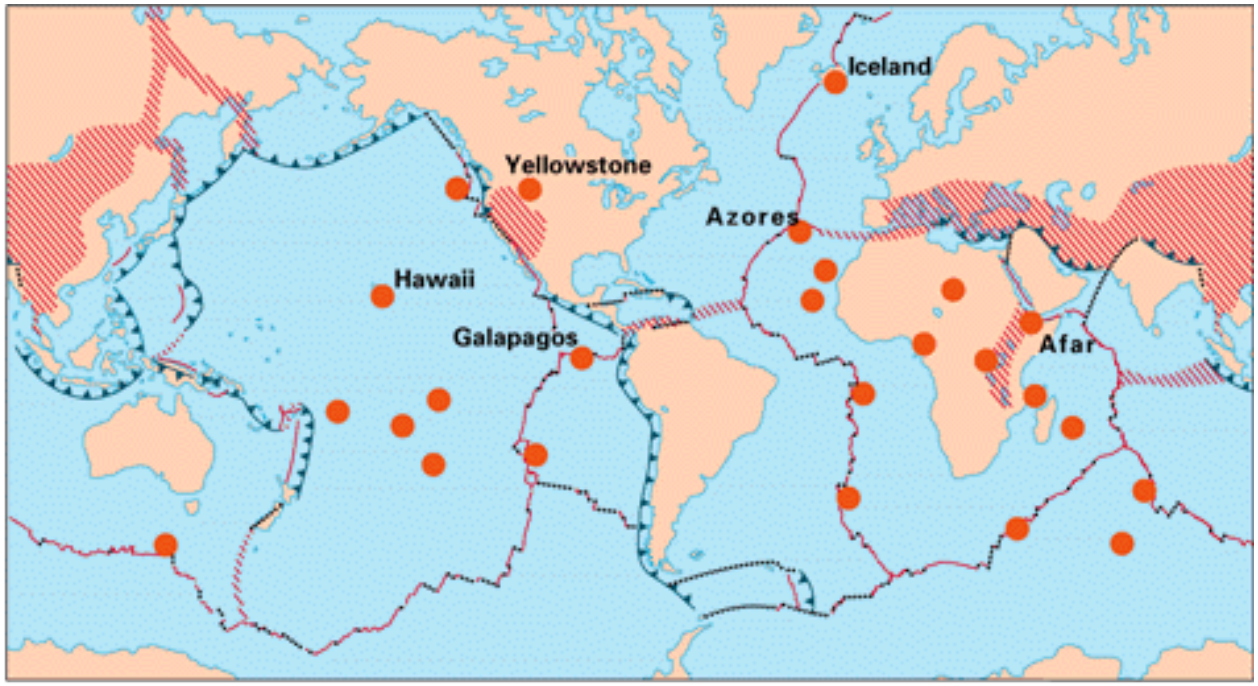




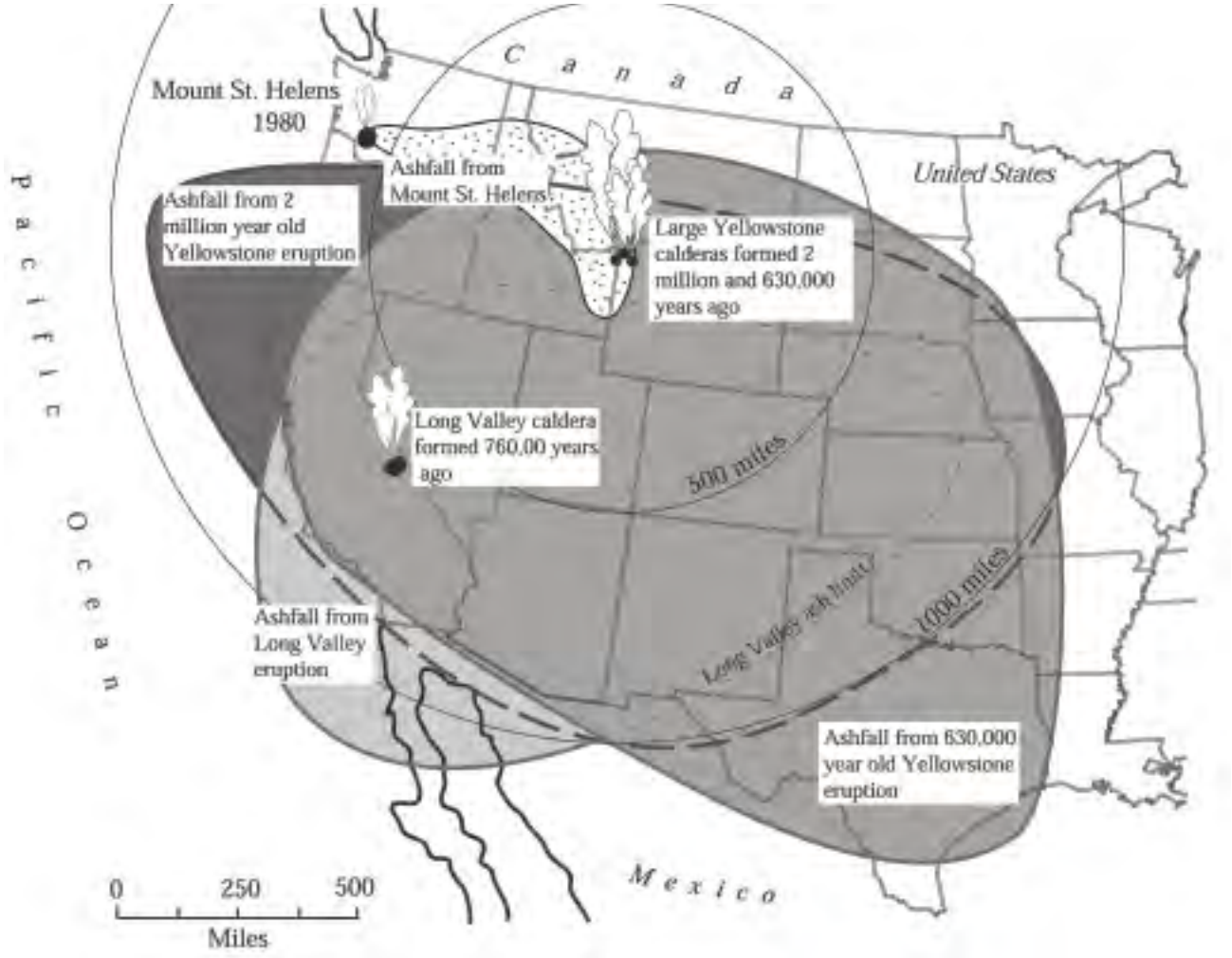
Tectonic plate moving over a hot spot

EXPLANATION

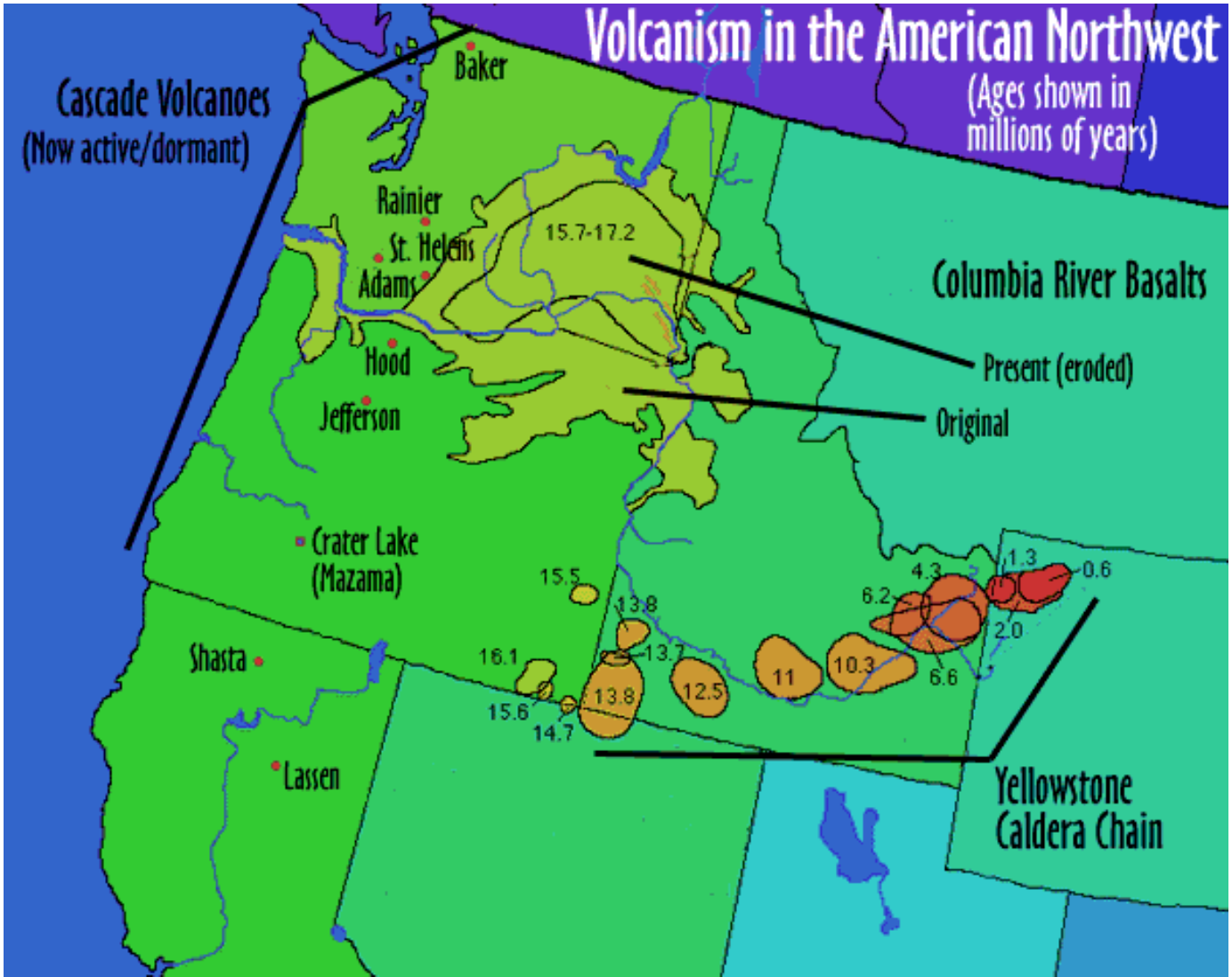
- **Divergent plate boundaries—** Where new crust is generated as the plates pull away from each other.
- **Convergent plate boundaries—** Where crust is consumed in the Earth's interior as one plate dives under another.
- **Transform plate boundaries—** Where crust is neither produced nor destroyed as plates slide horizontally past each other.
- **Plate boundary zones—Broad** belts in which deformation is diffuse and boundaries are not well defined.
- **Selected prominent hotspots**



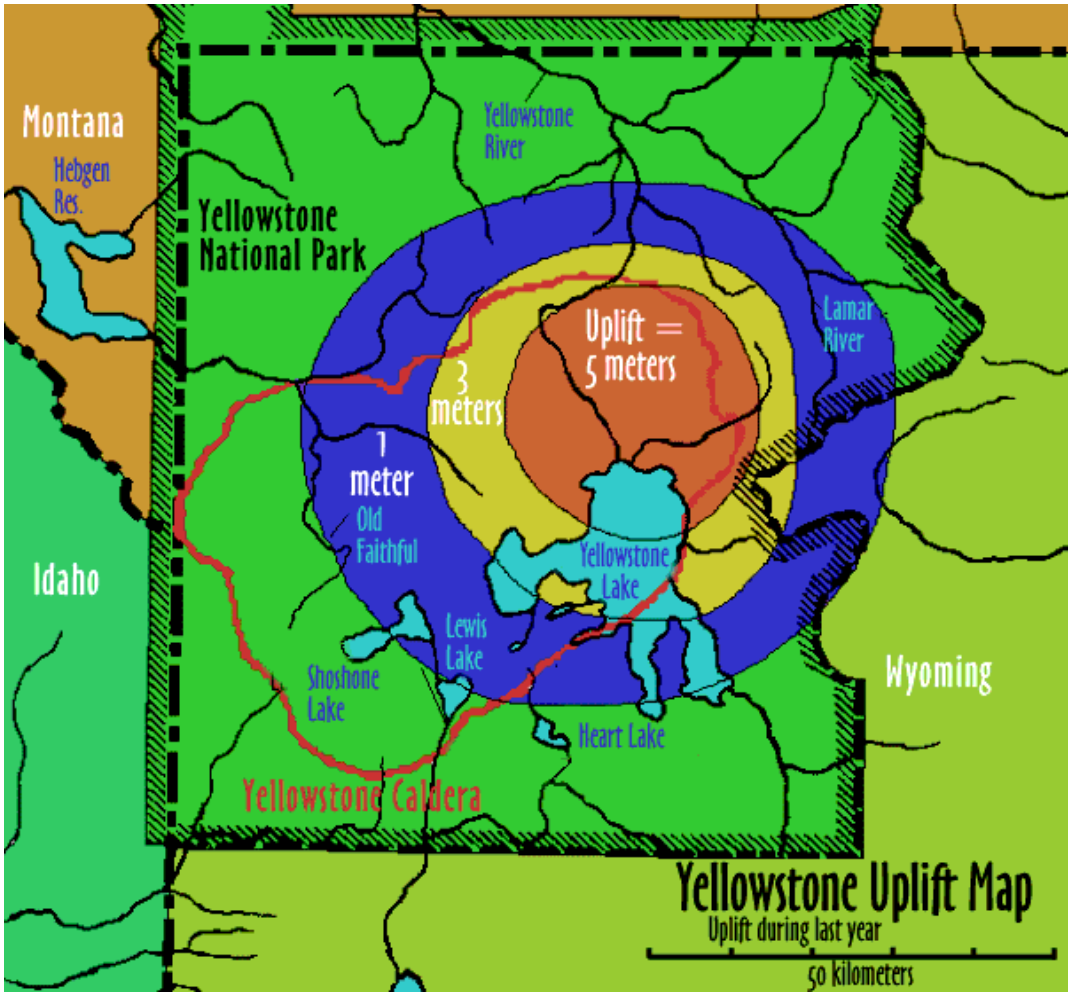
Tectonic plate moving over a hot spot



Tectonic plate moving over a hot spot



Tectonic plate moving over a hot spot



The nature of volcanic eruptions

- **Factors determining the "violence" or explosiveness of a volcanic eruption**
  - Composition of the magma (#Si = hi visc)
  - Temperature of the magma (lo T = hi visc)
  - Dissolved gases in the magma
    - 1-9 wt% of a magma
    - Mainly H_2O vapor & CO_2 (SO_2, N, Cl)

- **…factors actually control the viscosity of a given magma which in turn controls the nature of an eruption**

Materials extruded from a volcano

- **Felsic (rhyolitic)**
  - Si-rich, v. viscous; hi-H_2O & gas (pumice)
- **Intermediate (andesitic)**
  - more viscous (aa, vesicles; most explosive)
- **Mafic (basaltic)**
  - low Si = much more fluid-like
  - types of basaltic flows
    - Pahoehoe lava (resembles a twisted / ropey texture)
    - Aa lava (rough, jagged blocky texture)
    - Pillow basalts (underwater)

Pahoehoe lava flow

Typical aa flow

Pillow basalt

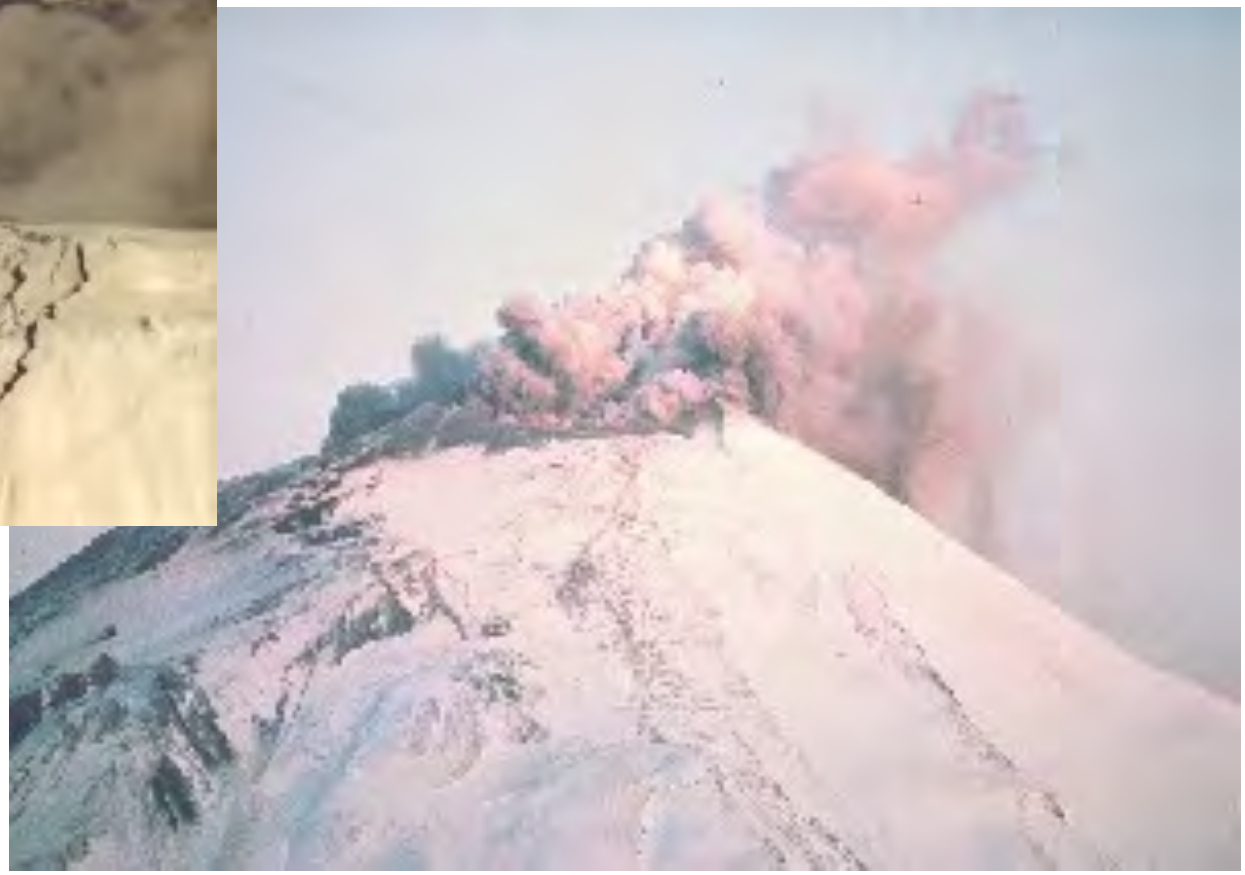
Materials extruded from a volcano

- **Pyroclastic materials – "fire fragments"**

  Types of pyroclastic debris

  - Ash & dust - fine, glassy fragments
  - Pumice - porous rock from 'frothy' lava
  - Lapilli - walnut-sized material
  - Cinders - pea-sized material
  - Particles larger than lapilli
    - Blocks - hardened or cooled lava (meters)
    - Bombs - ejected as hot lava; teardrop shape

Phreatic Eruption: steam from hot groundwater



Plinian Eruption
(Pliny the Elder)

Materials extruded from a volcano

- **Pyroclastic flows & surges**

- Mixture of hot (~500-700^{o}C) gas & rock that flows like an avalanche. Material size: ash to blocks
- Velocities from 10's - 100 m/sec; travel kms - 10 kms
- Generally confined to valleys
- Originate from column collapse or dome collapse
- "Ash hurricane" responsible for the holocaust at St. Pierre, Martinique, 1902; 30,000 people killed in minutes

Pyroclastic flows & surges

nueé ardente

• Fiery pyroclastic flow made of hot gases infused with ash and other debris

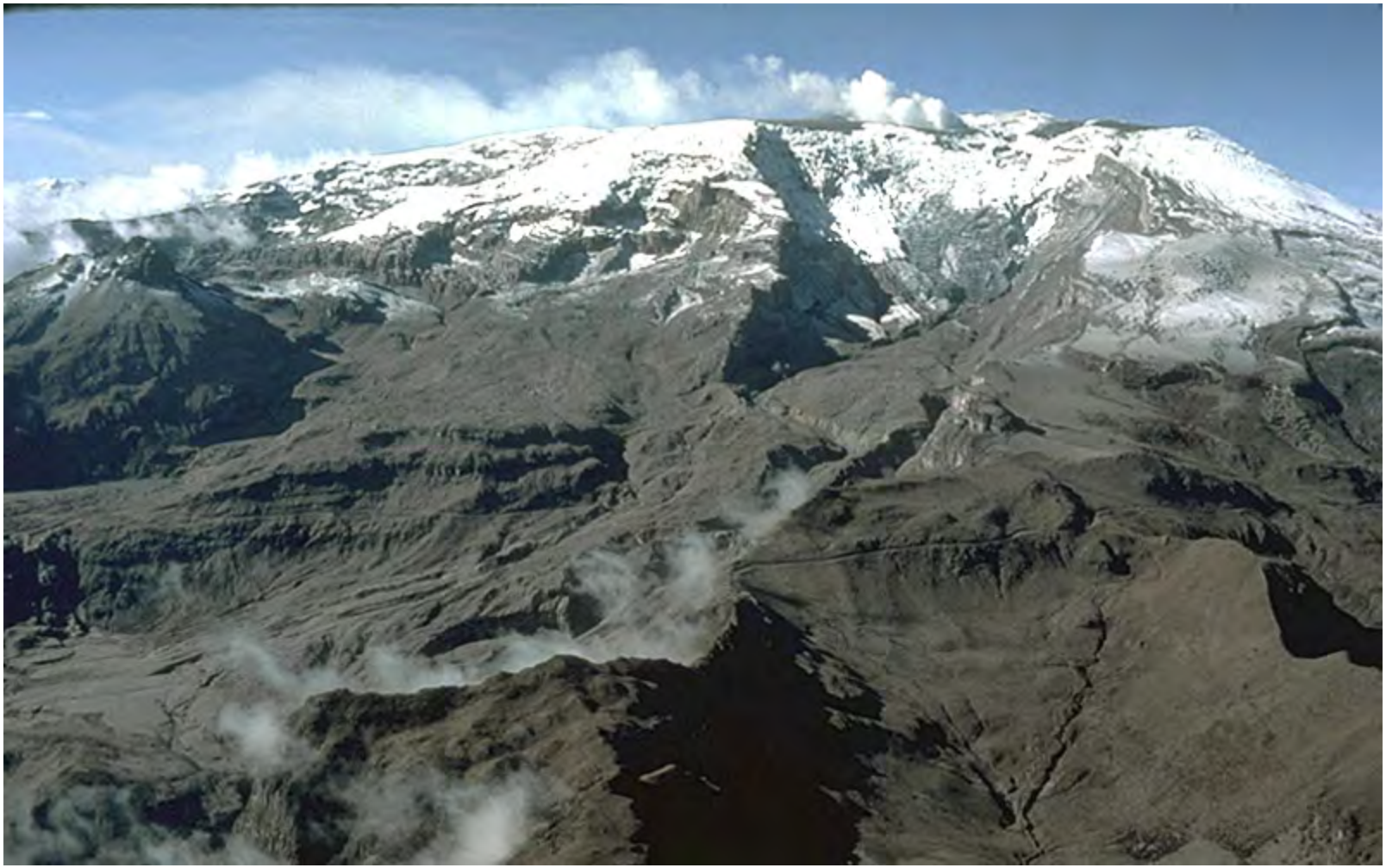
• Move down slopes at speeds up to 200 km/h

Pyroclastic flows & surges

lahar

- Water-saturated pyroclastic flow
- Melting glacier provides excess water

Nevado del Ruiz



Nevado del Ruiz


USGS
USGS Photo by Lyn Topinka, 1980

paleolahar
fossil lahar

Volcanic eruptions

- **Secondary effects**

- $SO_2 + H_2O_{atm} = H_2SO_4$ (acid rain)
- dust/ash = reflects sun radiation lowers T of Earth's surface by 2-3°C for as much as 10 yrs

Volcanoes

- **volcanic cone - hill or mountain**
- **volcanic crater / caldera - depression surrounding vent**

1) Effusive eruptions:

- from/near main vent = **shield volcano**
- from fissures (linear features) on land = **flood basalts**
- from subaqueous (= pillow basalts) & subglacial (= lahars)

Fissure

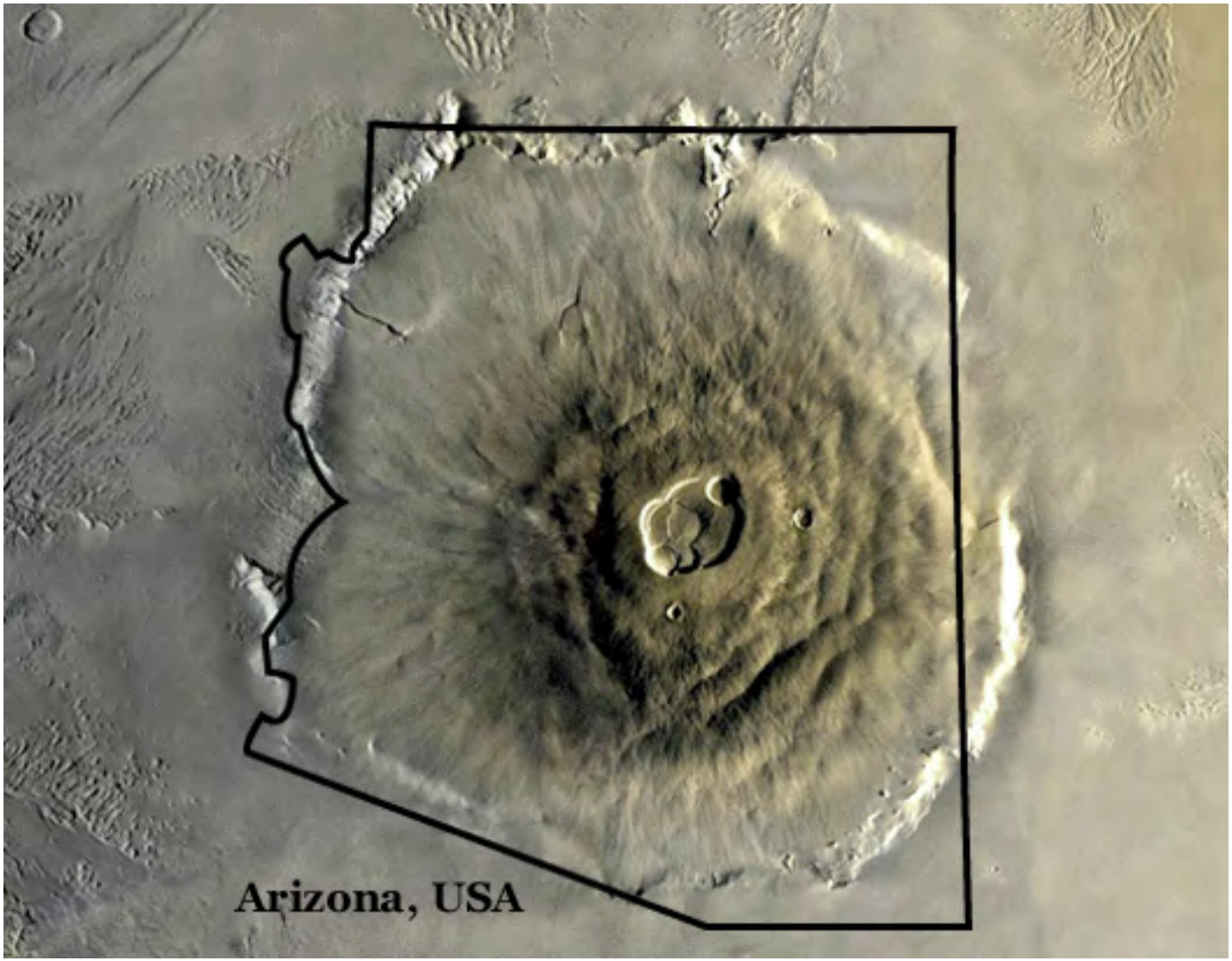
Lava Tube

Lava Tube

Shield volcano

- Mauna Loa is a classic shield volcano
- Slope angles are gentle, size is large
- Composition?

Shield Volcanoes: Olympus Mons



Volcanoes

2) Pyroclastic eruptions:

- airborne material w/ little / no magma .. v. viscous = tephra
- gas-rich, viscous magma = ash flow eruption

a) Composite cone (Stratovolcano)

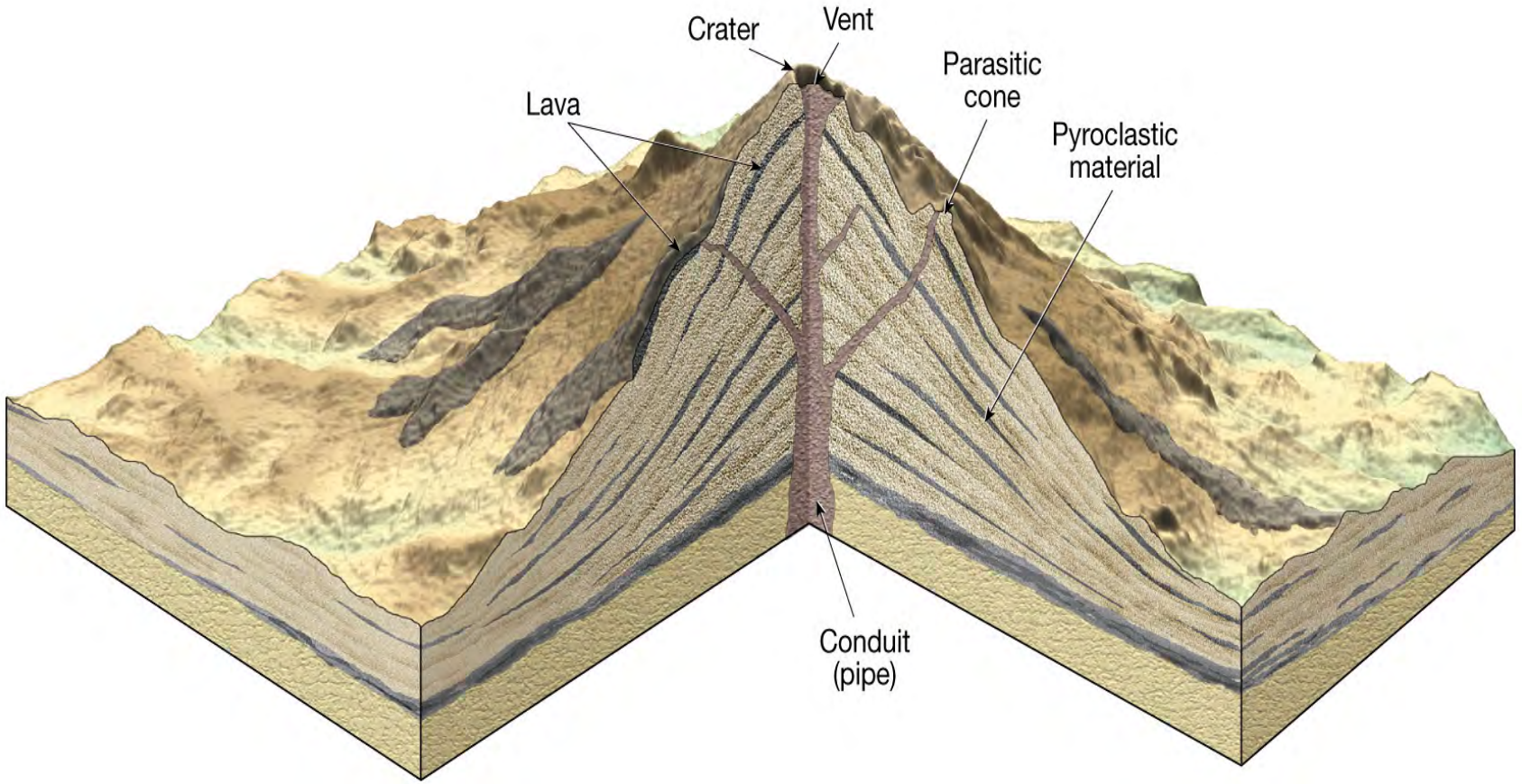
- Composed of interbedded lava flows and layers of pyroclastic debris
- Large, classic-shaped volcano (1000's of m high & several km wide at base)
- Most are located adjacent to the Pacific Ocean (e.g. Fujiyama, Mt. St. Helens, Ranier)

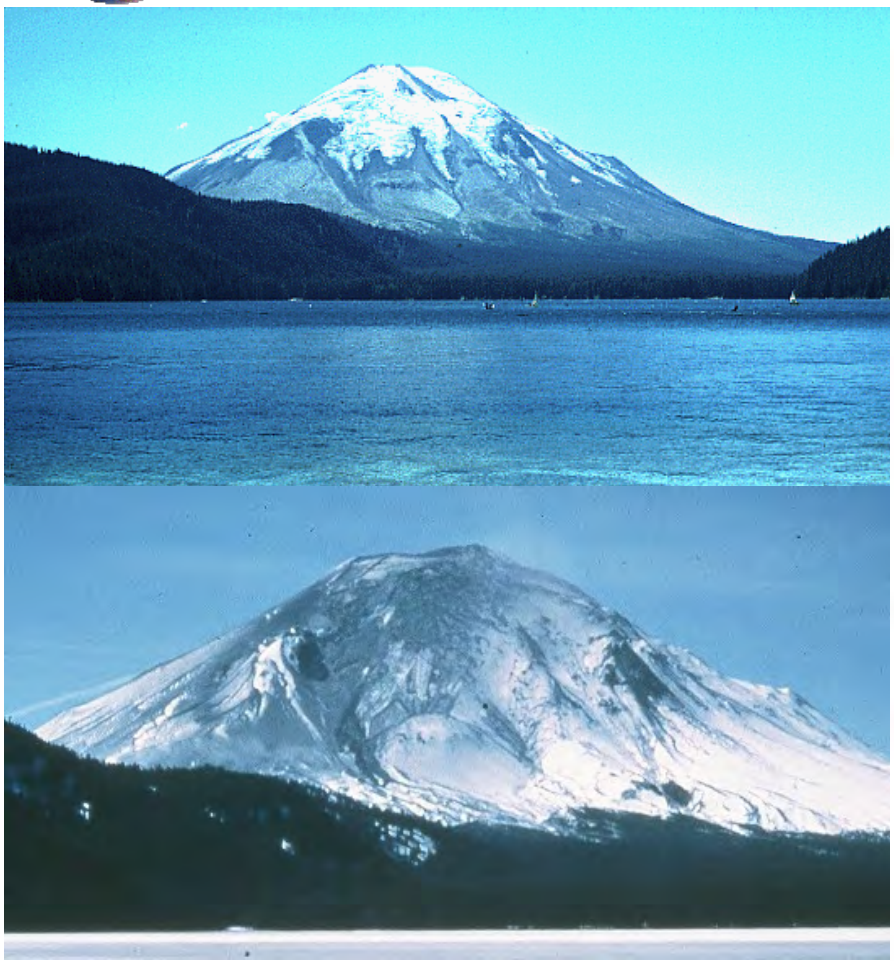
Volcanoes

a) Composite cones, cont.

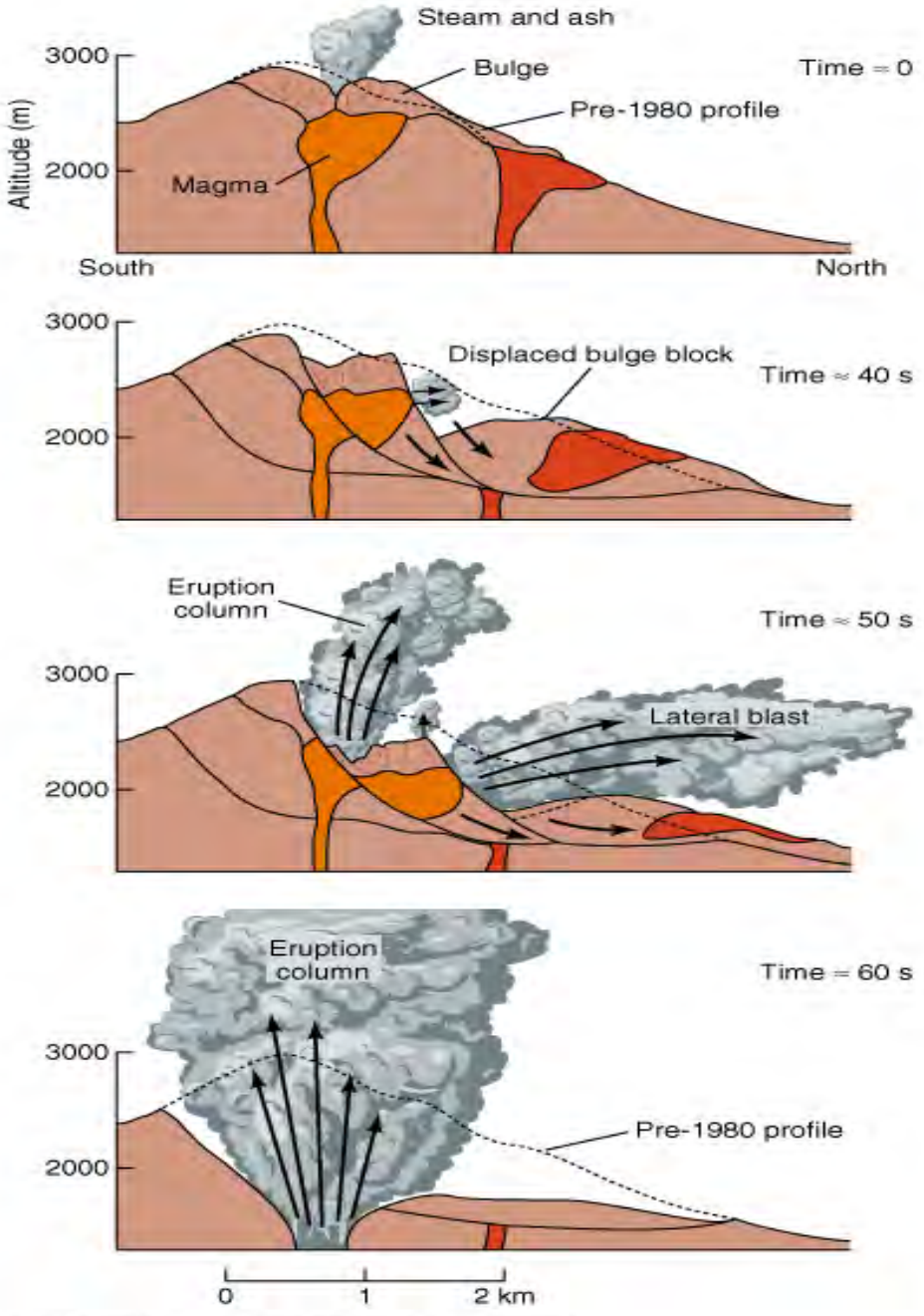
- most violent eruption (e.g. Mt. Vesuvius)
- often produce a nueé ardente
- may produce a lahar

A composite volcano

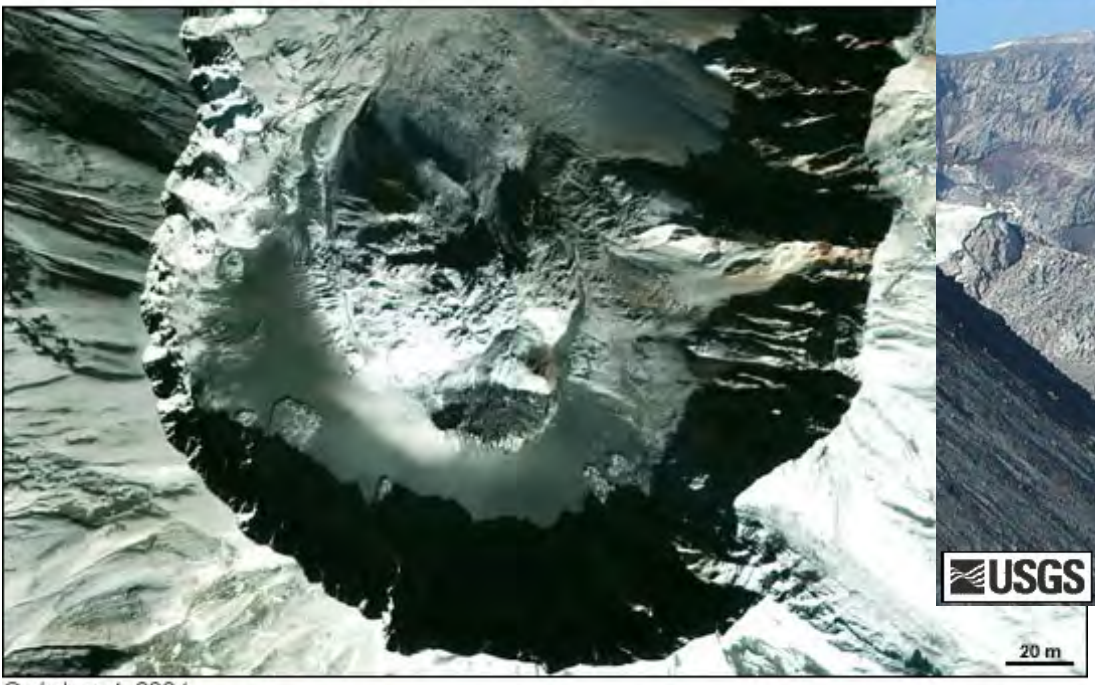




Mt St Helens: lateral blast



March 9, 2005



October 4, 2004

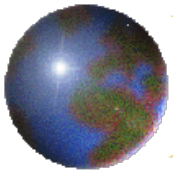
Volcanoes

b) Pyroclastic or cinder cone

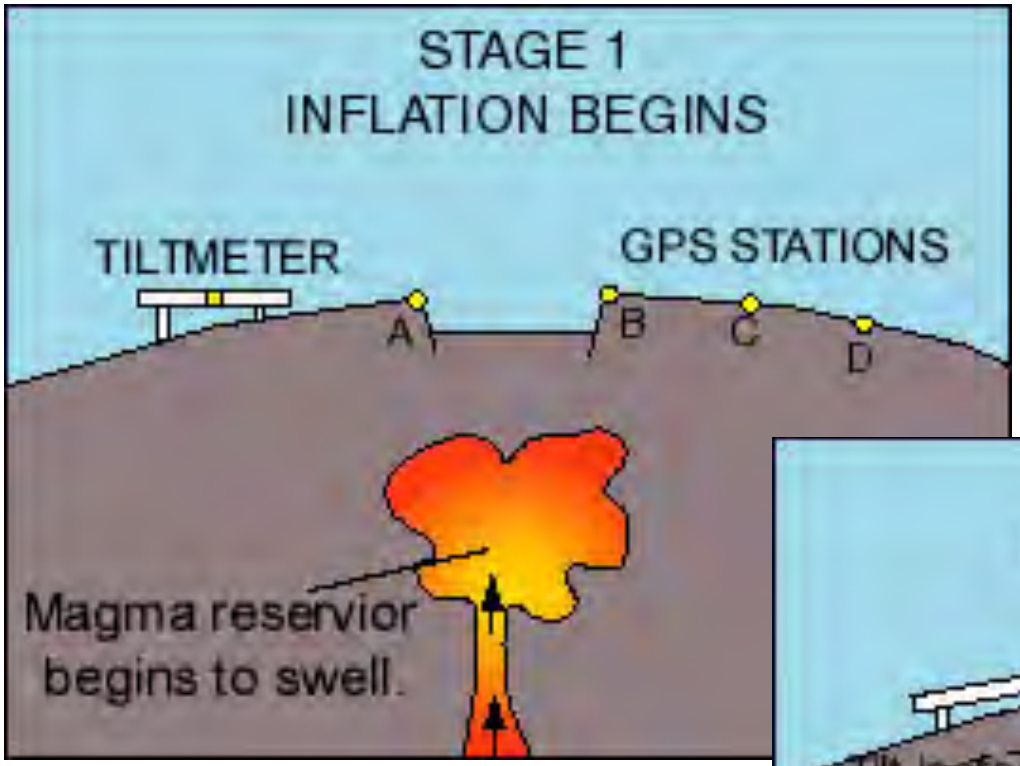
- loose pyroclastic material; small, steep sided; Sunset Crater, AZ

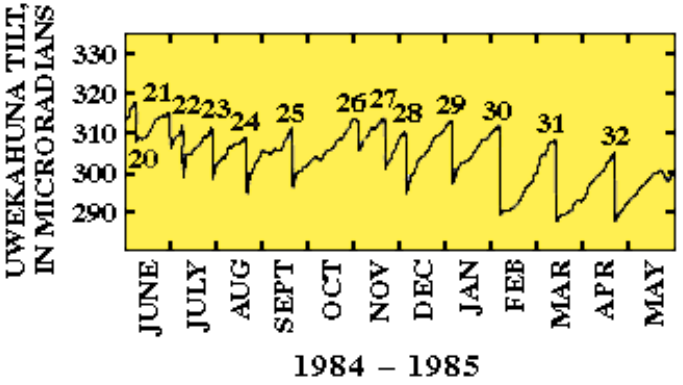
Volcanic landforms

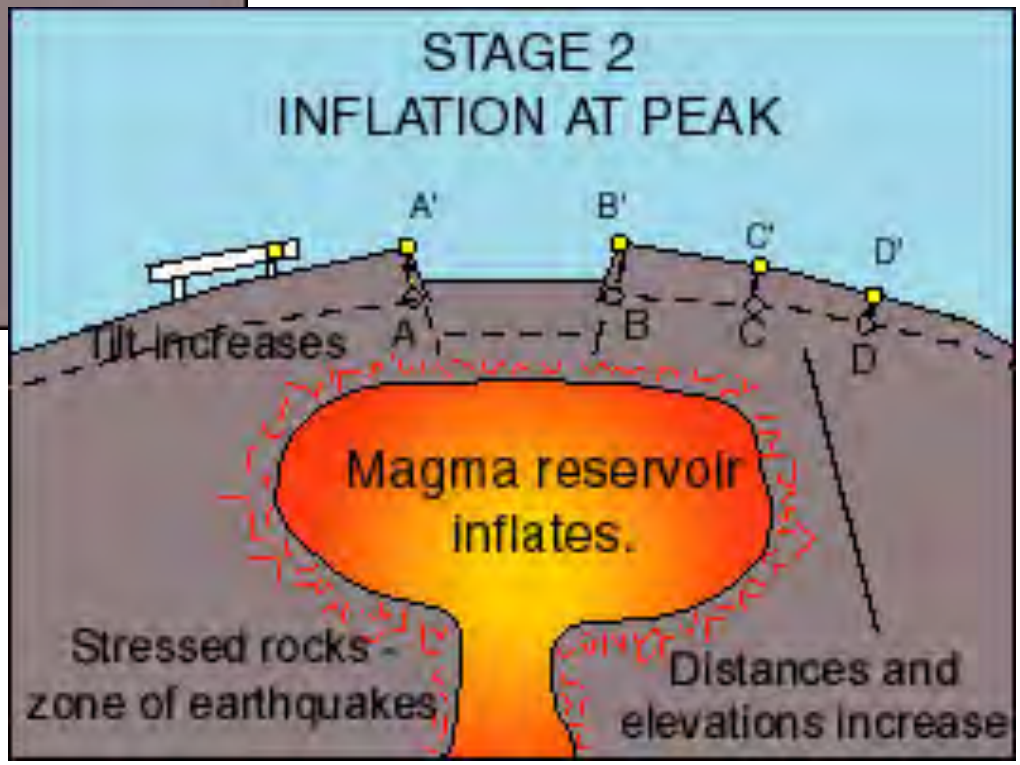
- **Lava Domes**
  - Bulbous mass of congealed lava
  - Most are associated with explosive eruptions of gas-rich magma
- **Volcanic pipes and necks**
  - Pipes are short conduits that connect a magma chamber to the surface

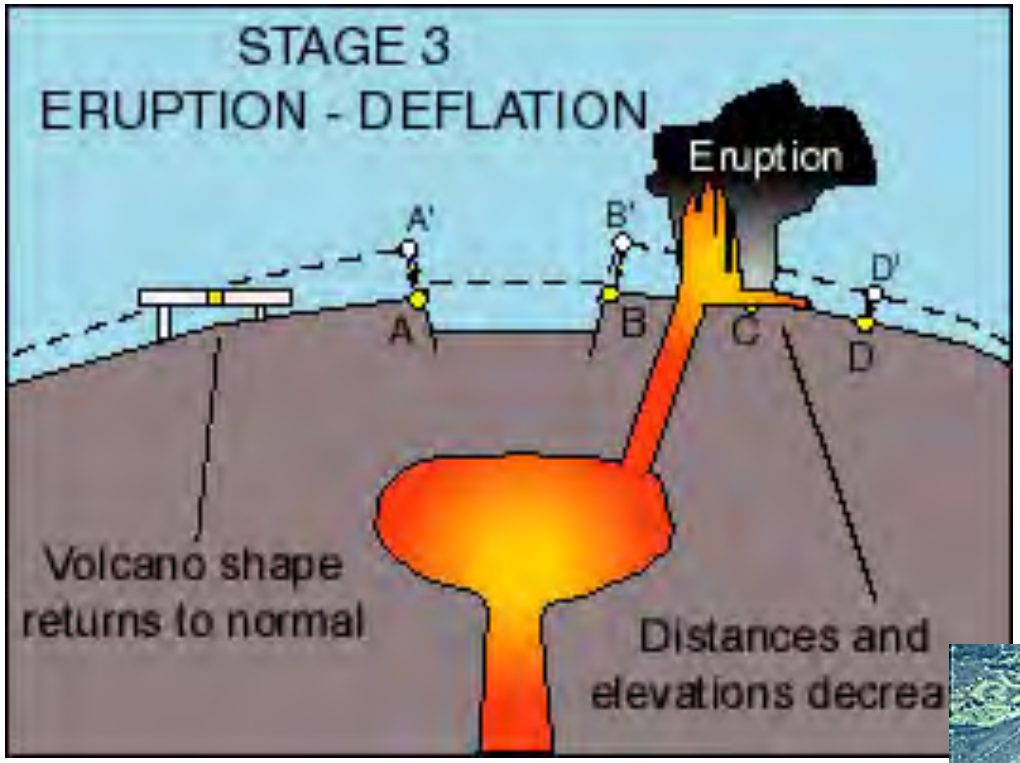


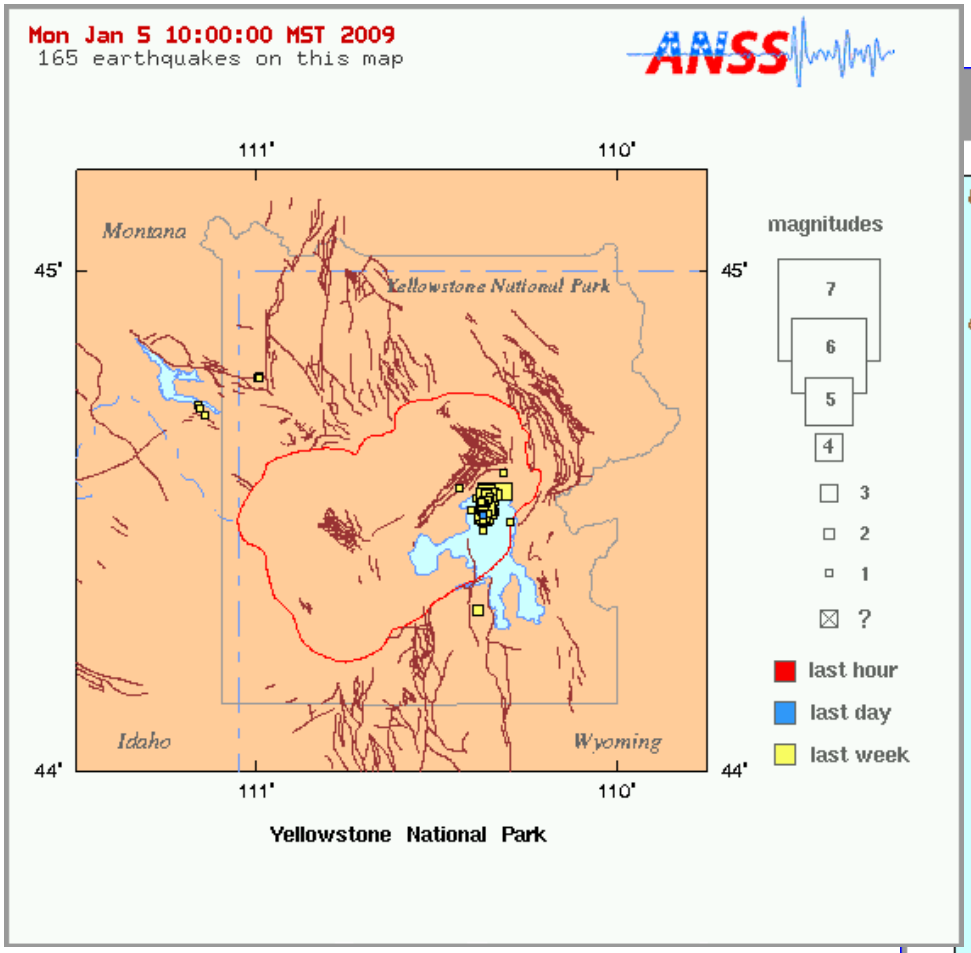
- **Volcanic precursors**
  - Increase of ground water temp (>20°C)
  - Topographic changes (tilt/bulge)
  - Increase in seismicity
  - Magnetic, electrical, gravity field changes
  - Changes in gas composition
  - Changes in animal behavior

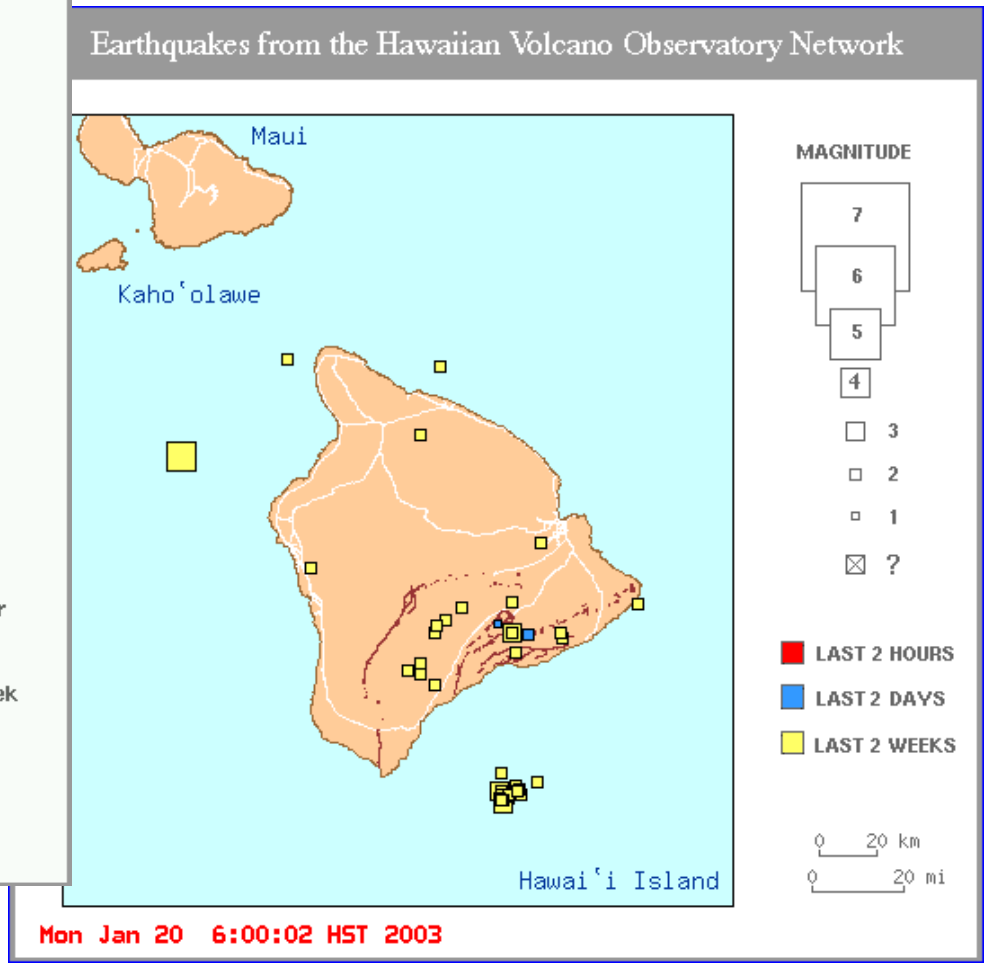

STAGE 1
INFLATION BEGINS
TILTMETER
GPS STATIONS
A
B
C
D
Magma reservior
begins to swell.

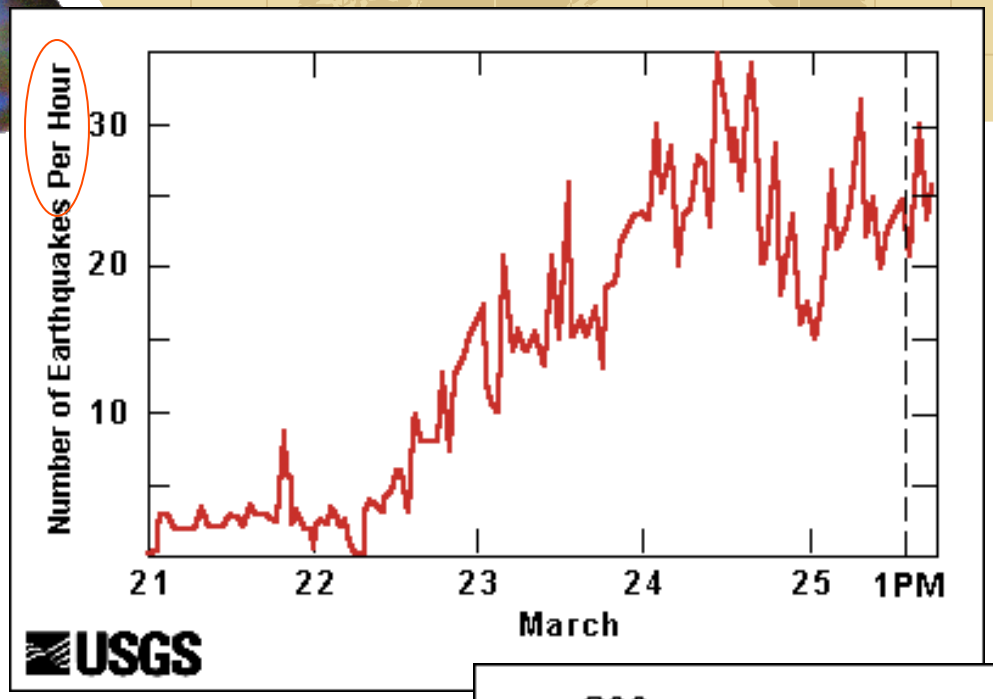

UWEKAHUNA TILT,
IN MICRORADIANS
330
320
310
300
290
20
21
22
23
24
25
26
27
28
29
30
31
32
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
1984 – 1985

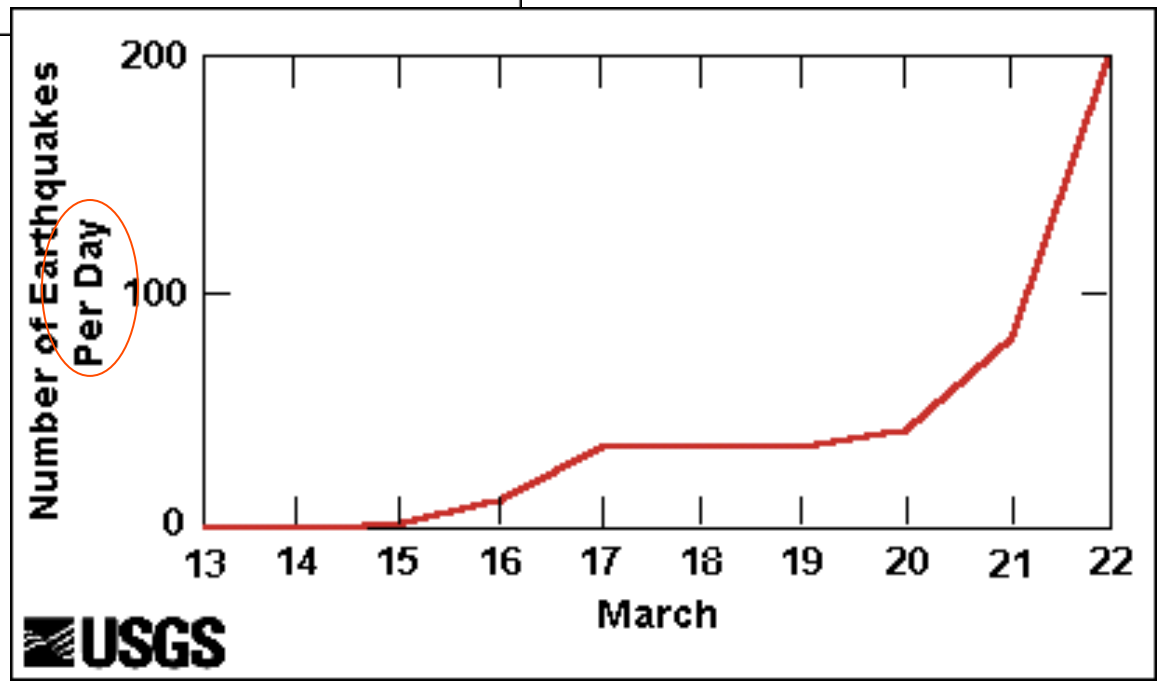

STAGE 2
INFLATION AT PEAK
A'
B'
C'
D'
Tilt increases
A
B
C
D
Magma reservoir
inflates.
Stressed rocks -
zone of earthquakes
Distances and
elevations increase


STAGE 3
ERUPTION - DEFLATION
Eruption
A'
B'
D'
A
B
C
D
Volcano shape
returns to normal
Distances and
elevations decrea

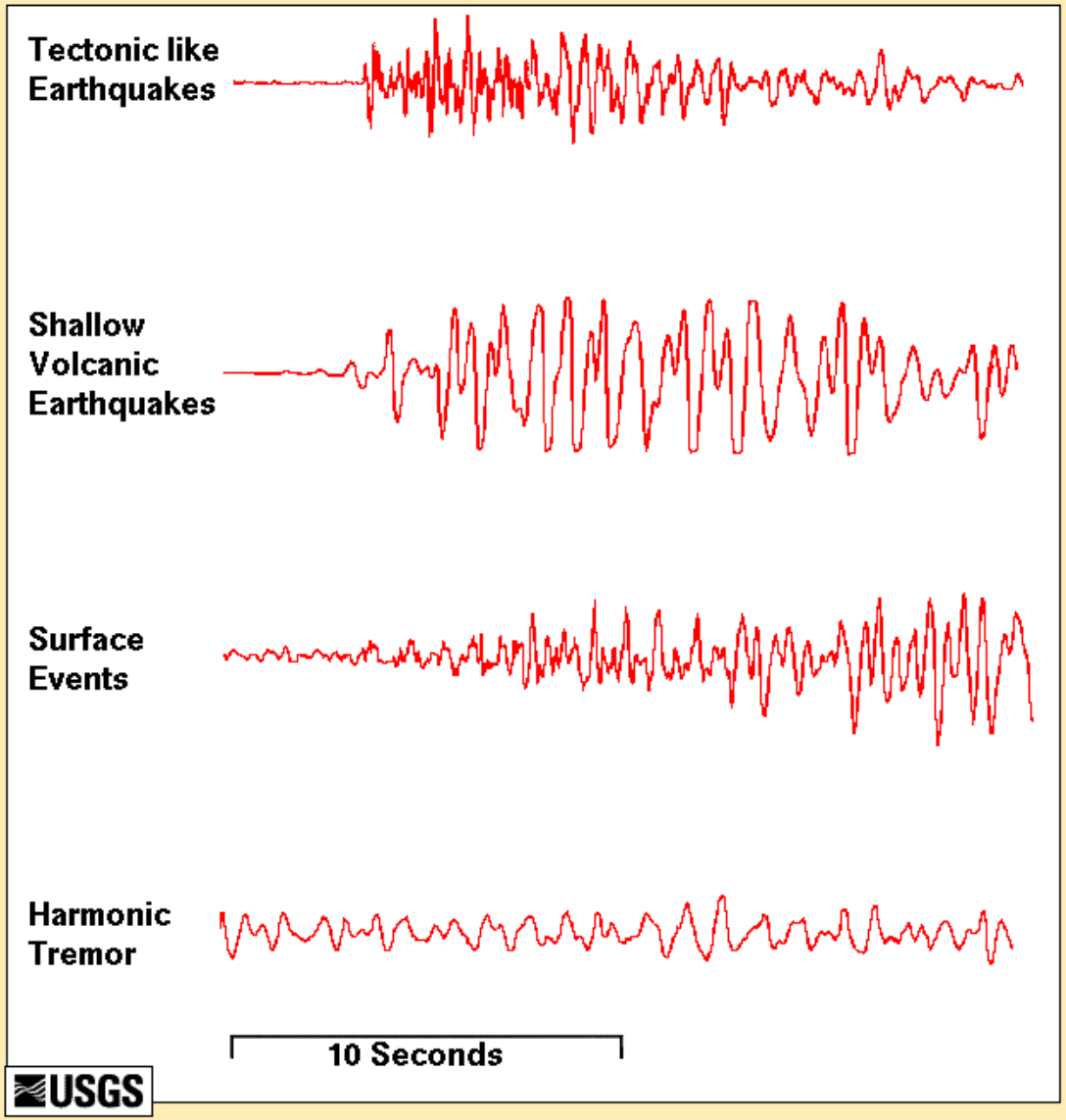

Mon Jan 5 10:00:00 MST 2009
165 earthquakes on this map
ANSS
111'
110'
45'
44'
Montana
Yellowstone National Park
Idaho
Wyoming
magnitudes
7
6
5
4
3
2
1
?
last hour
last day
last week
Yellowstone National Park


Earthquakes from the Hawaiian Volcano Observatory Network
Maui
Kaho'olawe
Hawai'i Island
MAGNITUDE
7
6
5
4
3
2
1
?
LAST 2 HOURS
LAST 2 DAYS
LAST 2 WEEKS
0 20 km
0 20 mi
Mon Jan 20 6:00:02 HST 2003


Number of Earthquakes Per Hour
30
20
10
21
22
23
24
25
1PM
March
USGS


Number of Earthquakes Per Day
200
100
0
13
14
15
16
17
18
19
20
21
22
March
USGS

Four Major Types of Seismograms



USGS

Topinka, USGS/CVO, 1997, Modified from: Brantley and Topinka, 1984, Earthquake Information Bulletin

Plutonic activity

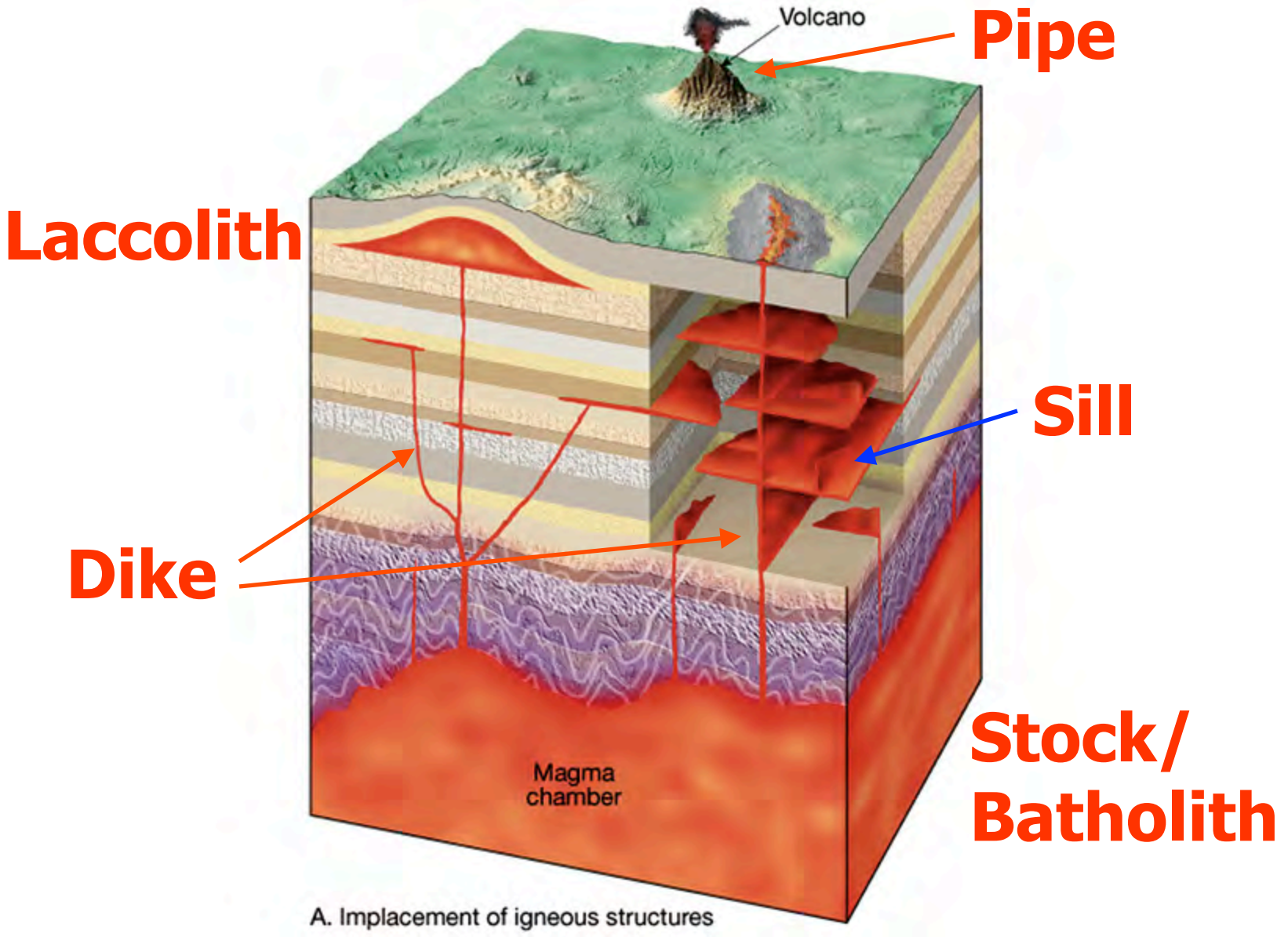
- **Most magma is emplaced at depth in the Earth**
  - An underground igneous body, once cooled and solidified, is called a pluton
- **Classification of plutons**
  - Shape
    - Tabular (sheetlike)
    - Massive (irregular)
  - Orientation with respect to the host (surrounding) rock
    - Discordant – cuts across rock units
    - Concordant – parallel to rock units

Plutonic activity

- **Types of intrusive igneous features**
  - Dike – a tabular, discordant pluton
  - Sill – a tabular, concordant pluton (e.g., Palisades Sill in New York)
  - Laccolith
    - Similar to a sill
    - Lens or mushroom-shaped mass
    - Arches overlying strata upward

Plutonic activity

- **Intrusive igneous features**
  - Batholith
    - Largest intrusive body
    - Surface exposure of 100+ km^2 (smaller bodies are termed stocks)
    - Frequently form the cores of mountains


Volcano
Pipe
Laccolith
Sill
Dike
Magma chamber
Stock/
Batholith
A. Implacement of igneous structures