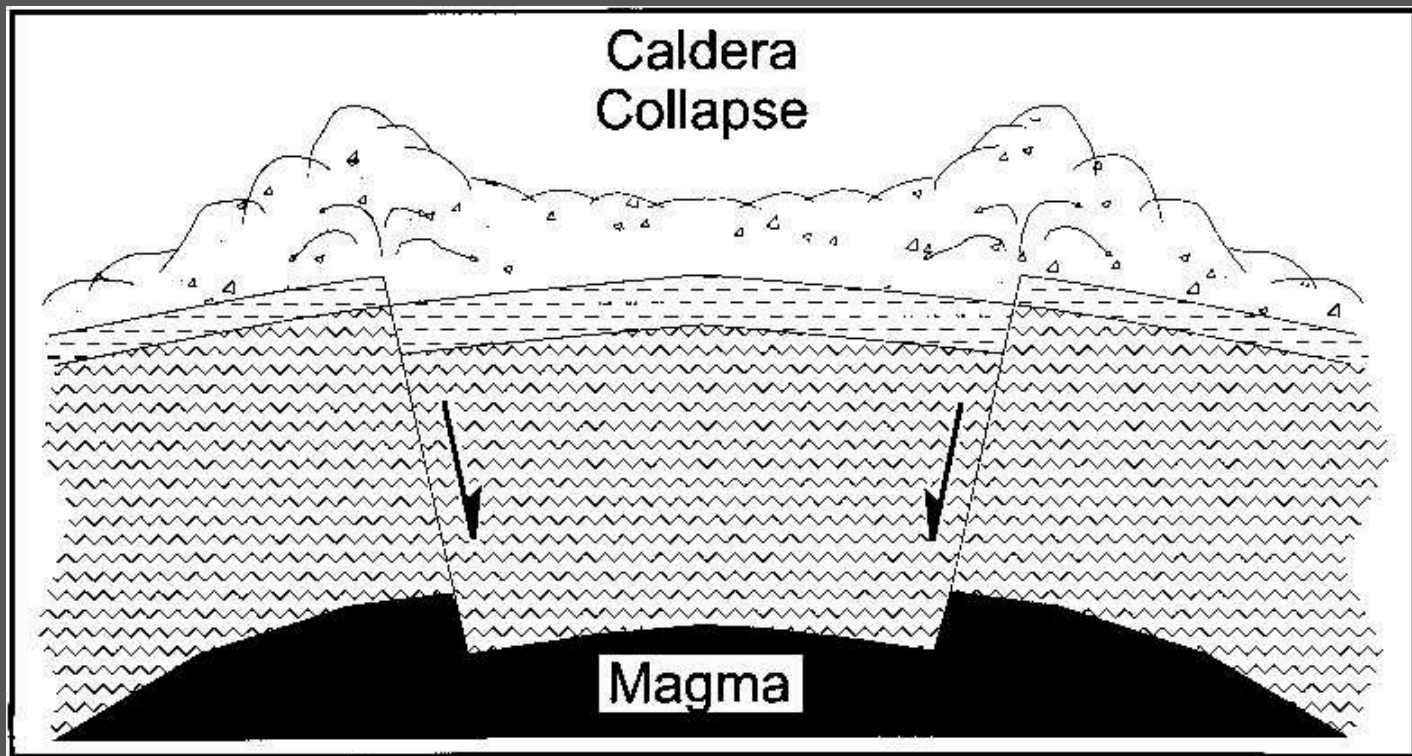


Caldera-forming eruptions

Matthew Zimmerer – matthew.zimmerer@nmt.edu - Bureau 329



What is Magma?

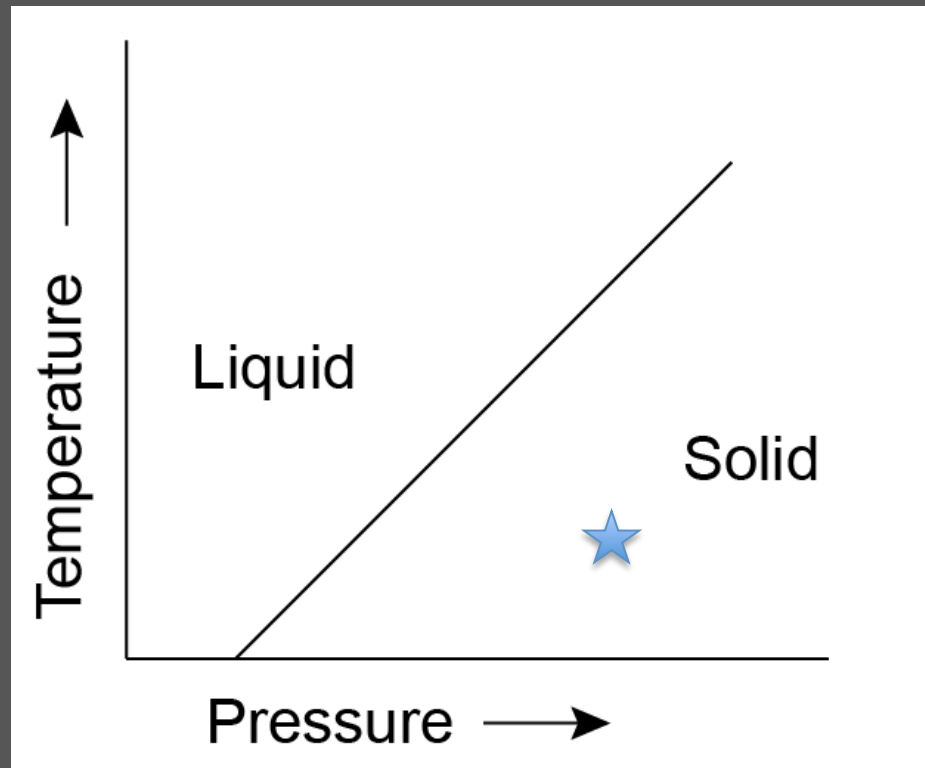


What is Magma?

***Magma:** naturally occurring, fully or partially molten rock material generated within a planetary body, consisting of melt with or without crystals and gas bubbles and containing a high enough proportion of melt to be capable of intrusion and extrusion.*

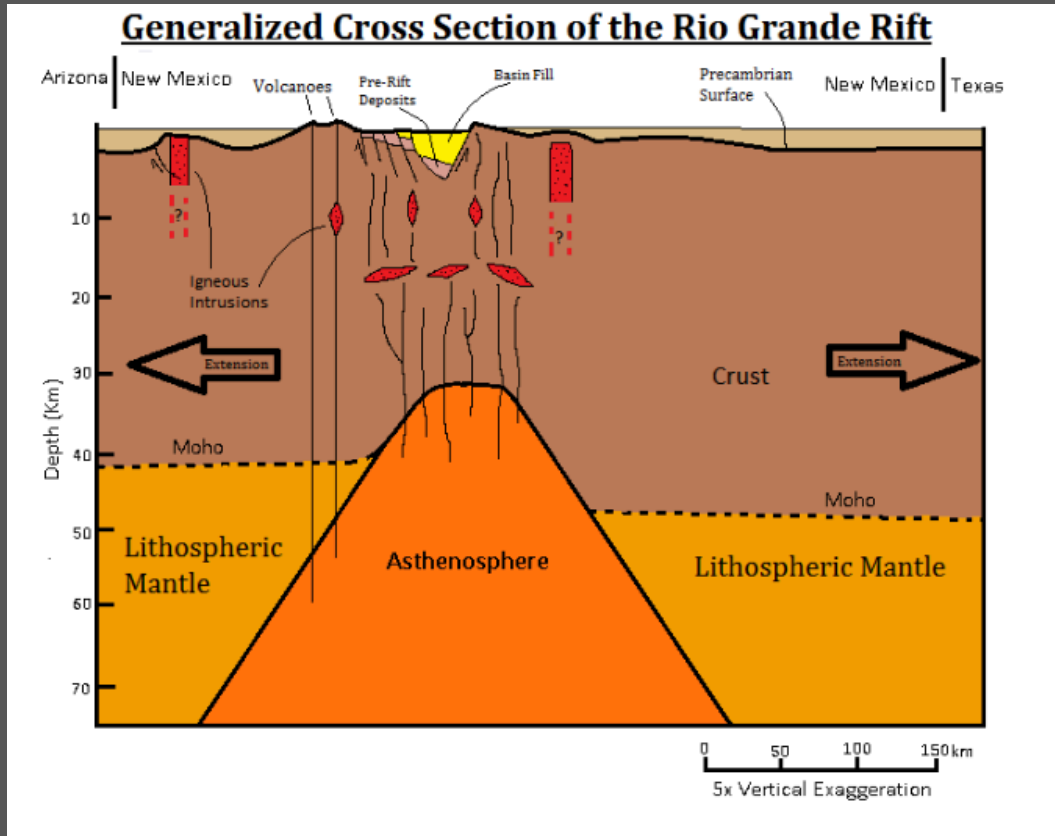
How is magma made?

How is magma made?

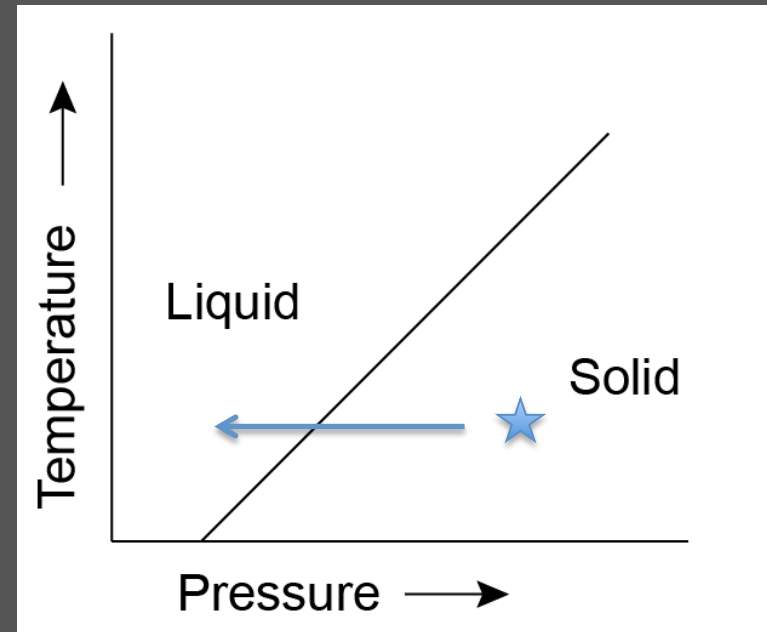


2 component phase diagram

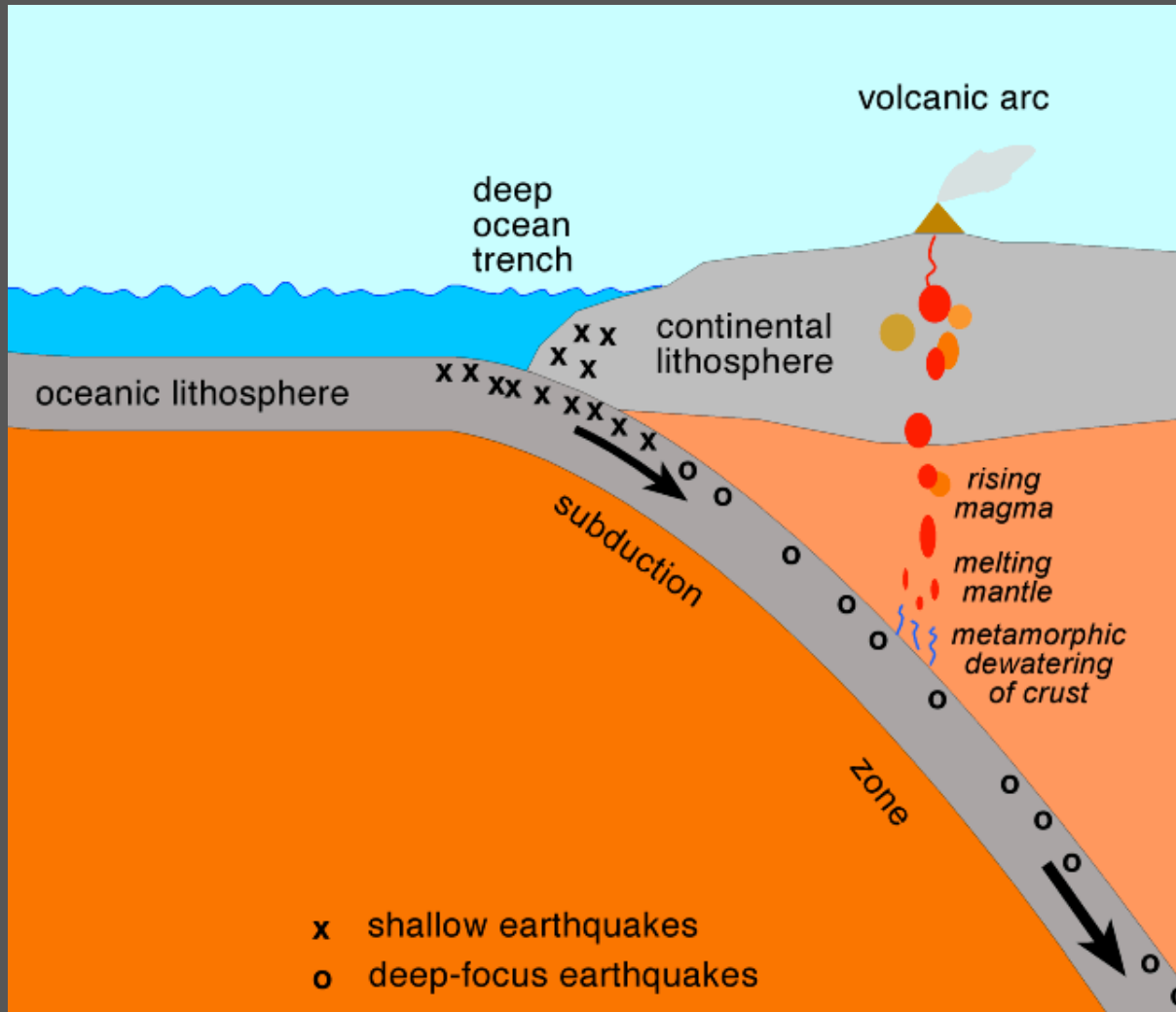
How is magma made?



Decompression Melting



How is magma made?



Flux
Melting
Of the
Mantle

Magma Differentiation

What is differentiation?

Magma Differentiation

Processes that change
the composition of a
magma

Magma Differentiation

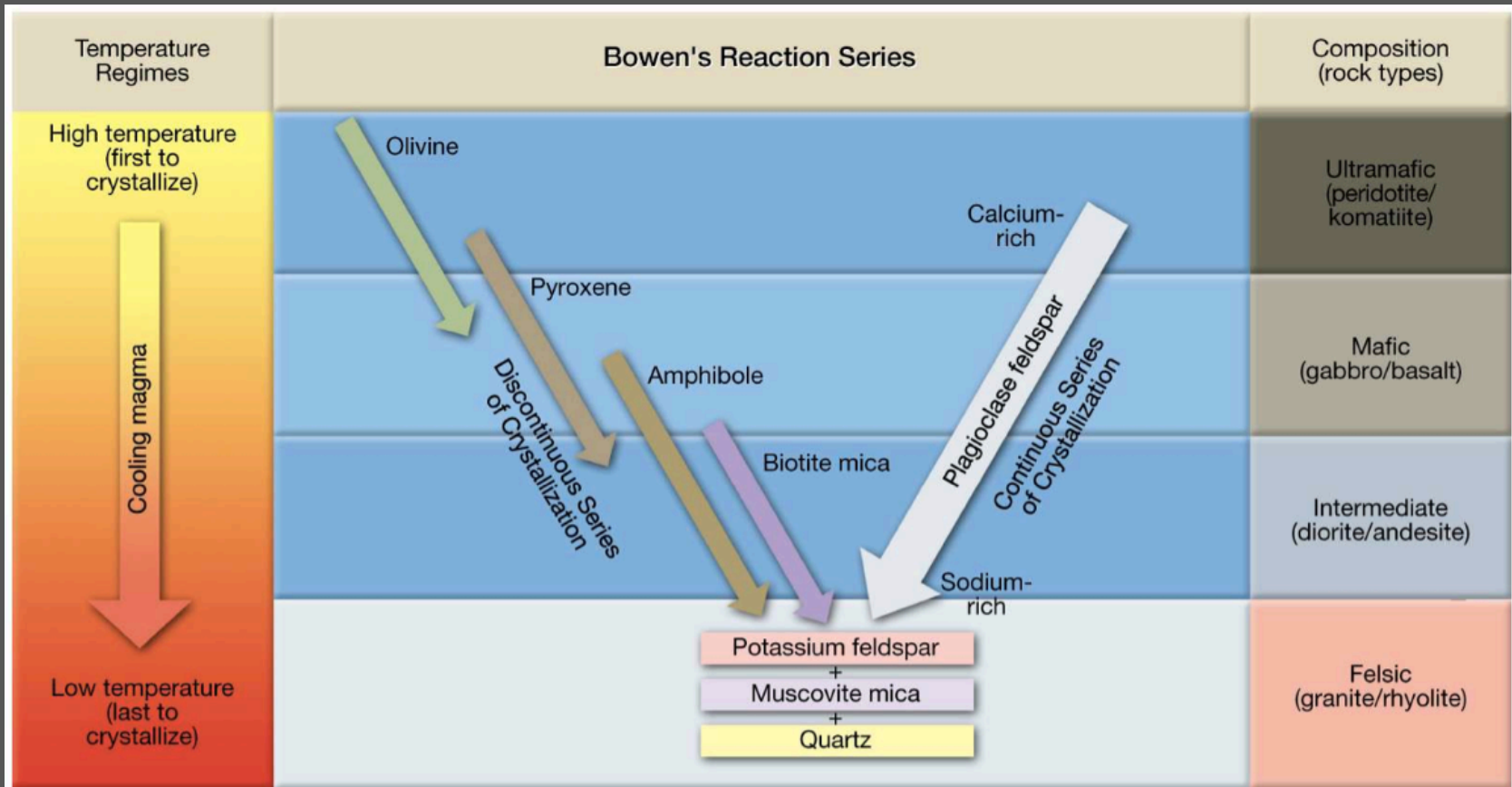
1 – Crystal Fractionation

2 – Magma Mixing

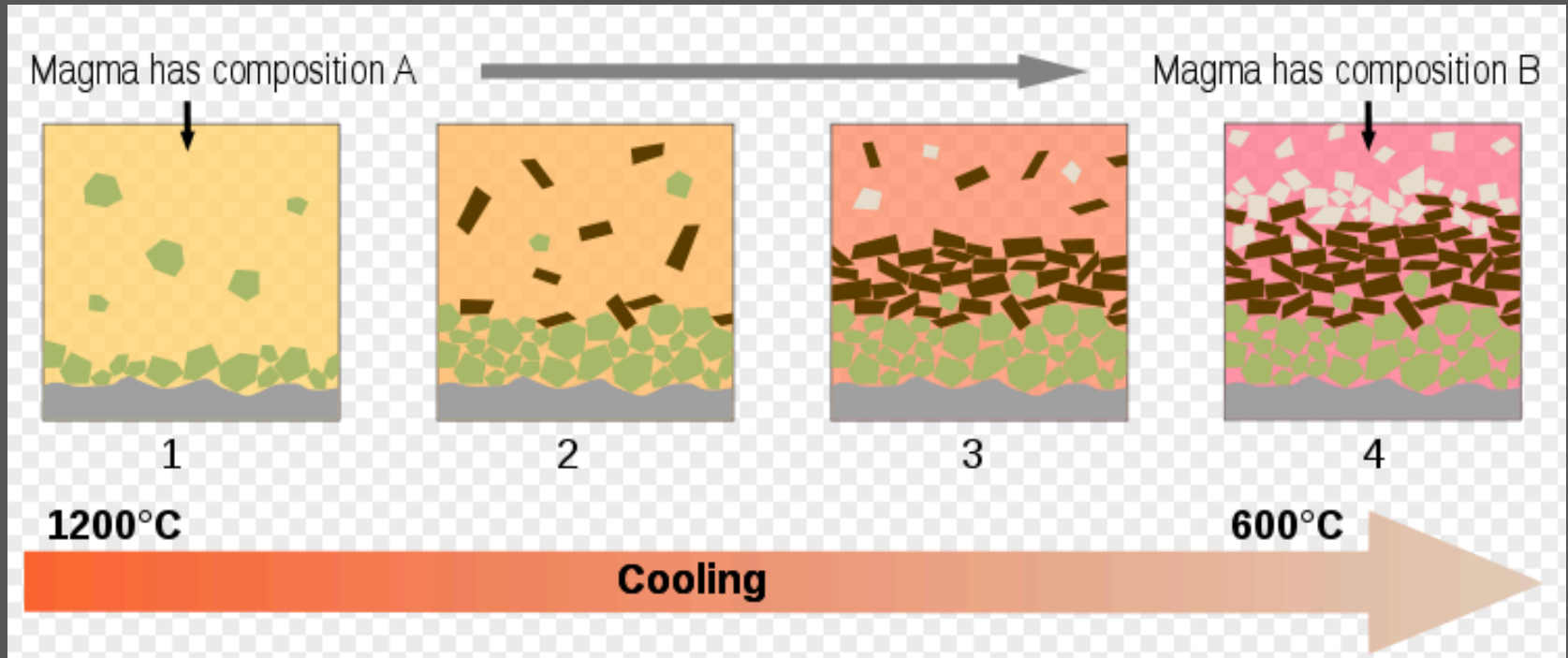
3 – Assimilation

4 – Partial Melting

Crystal Fractionation

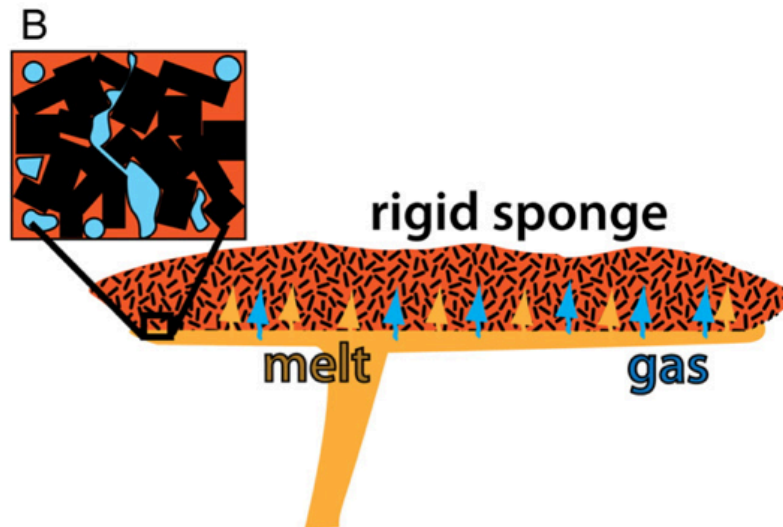
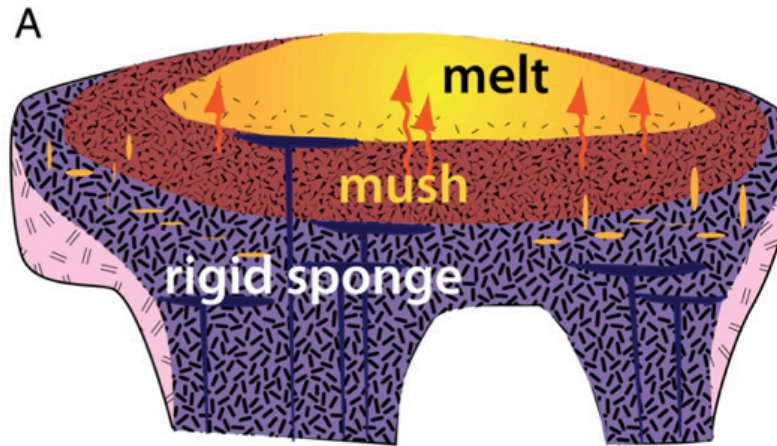


Crystal Fractionation



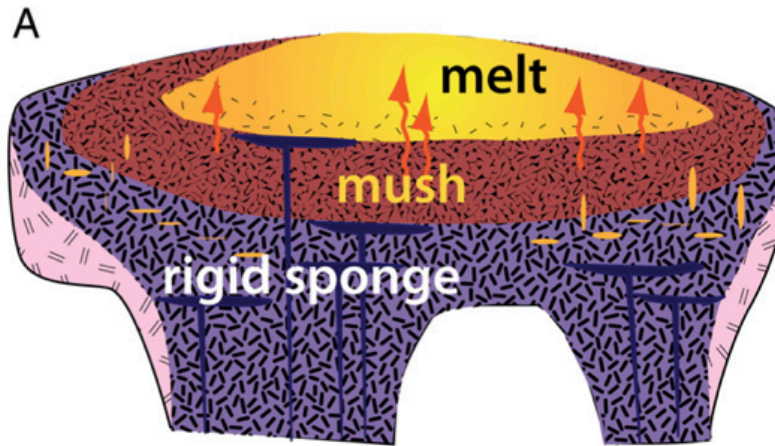
Crystal Settling – Locally important,
but probably not a large-scale mechanism
for silicic magmas

Crystal Mush Model for Fractionation

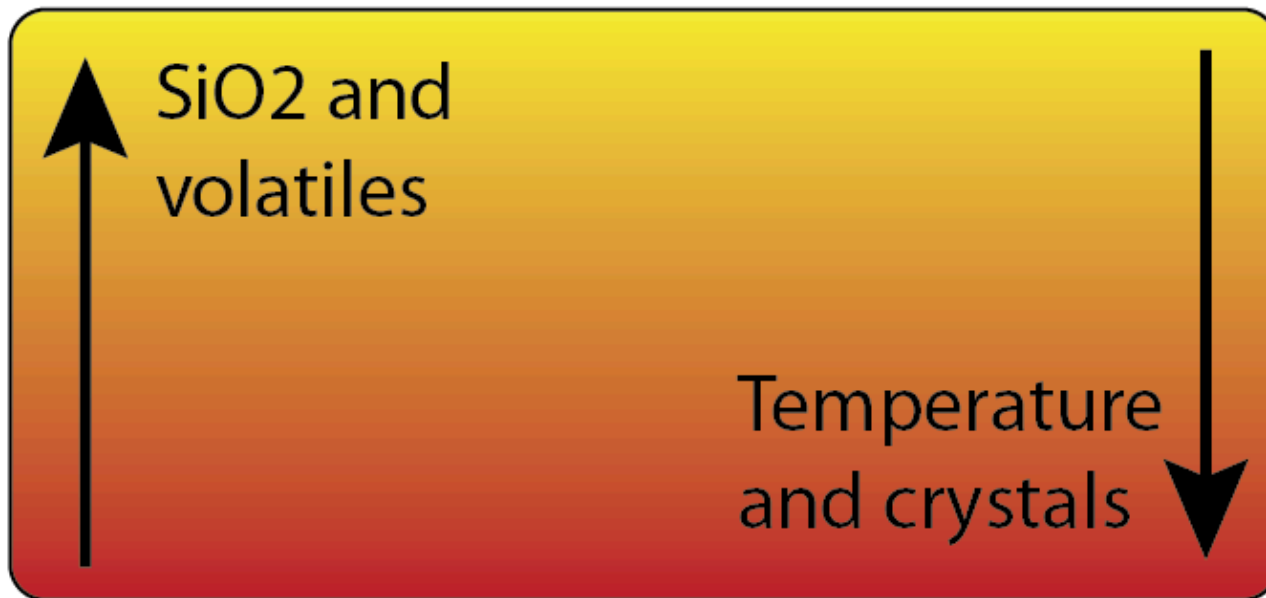


At 40-60% crystals, the crystal mush becomes “locked” and is no longer stirring

Crystal Mush Model for Fractionation



At 40-60% crystals, the crystal mush becomes “locked” and is no longer stirring



Crystal Mush Model for Fractionation

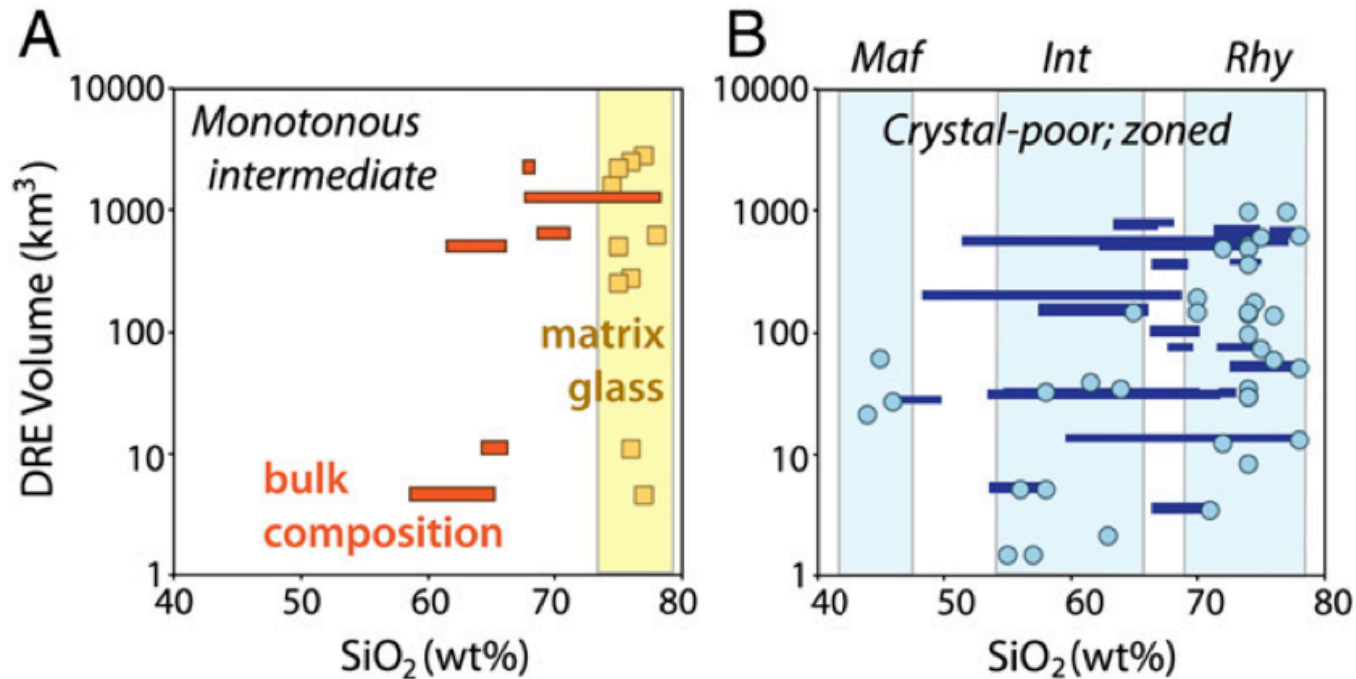


Fig. 4. Bulk rock and matrix glass compositions of CP and CR ignimbrites as a function of DRE erupted volume. (A) CR data; yellow squares show matrix glass, orange bars show bulk compositional range. (B) CP data; blue circles show matrix glass composition of earliest erupted magma, blue bars show bulk compositional range. Data sources are listed in Table S1.

Deep processes

Annen et al. 2006

Magma differentiation processes:

- Partial melting of protolith (fertile vs. refractory) by basalt intrusions

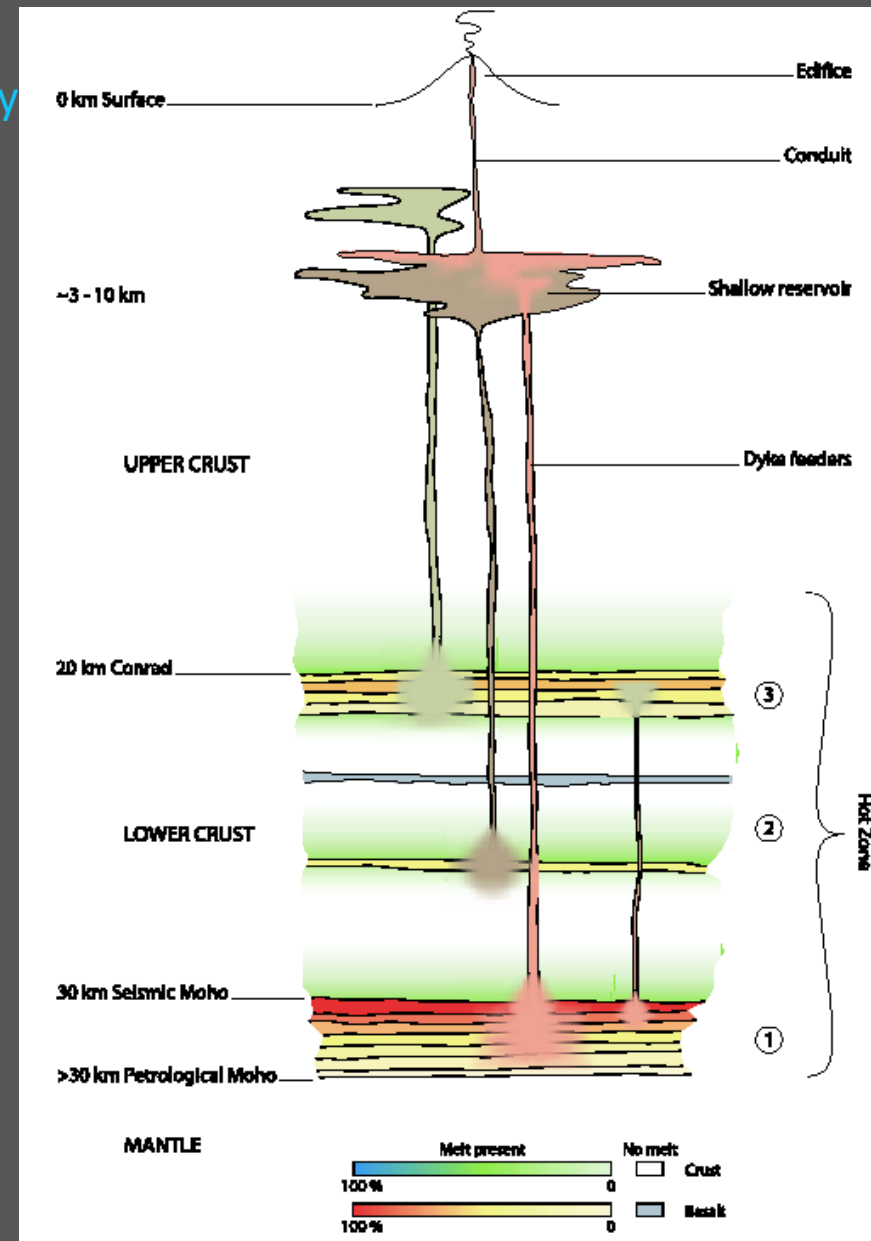
- H₂O-poor, high viscosity
- Presence/absence of hydrous minerals
- Dehydration melting
- Peraluminous liquids produced

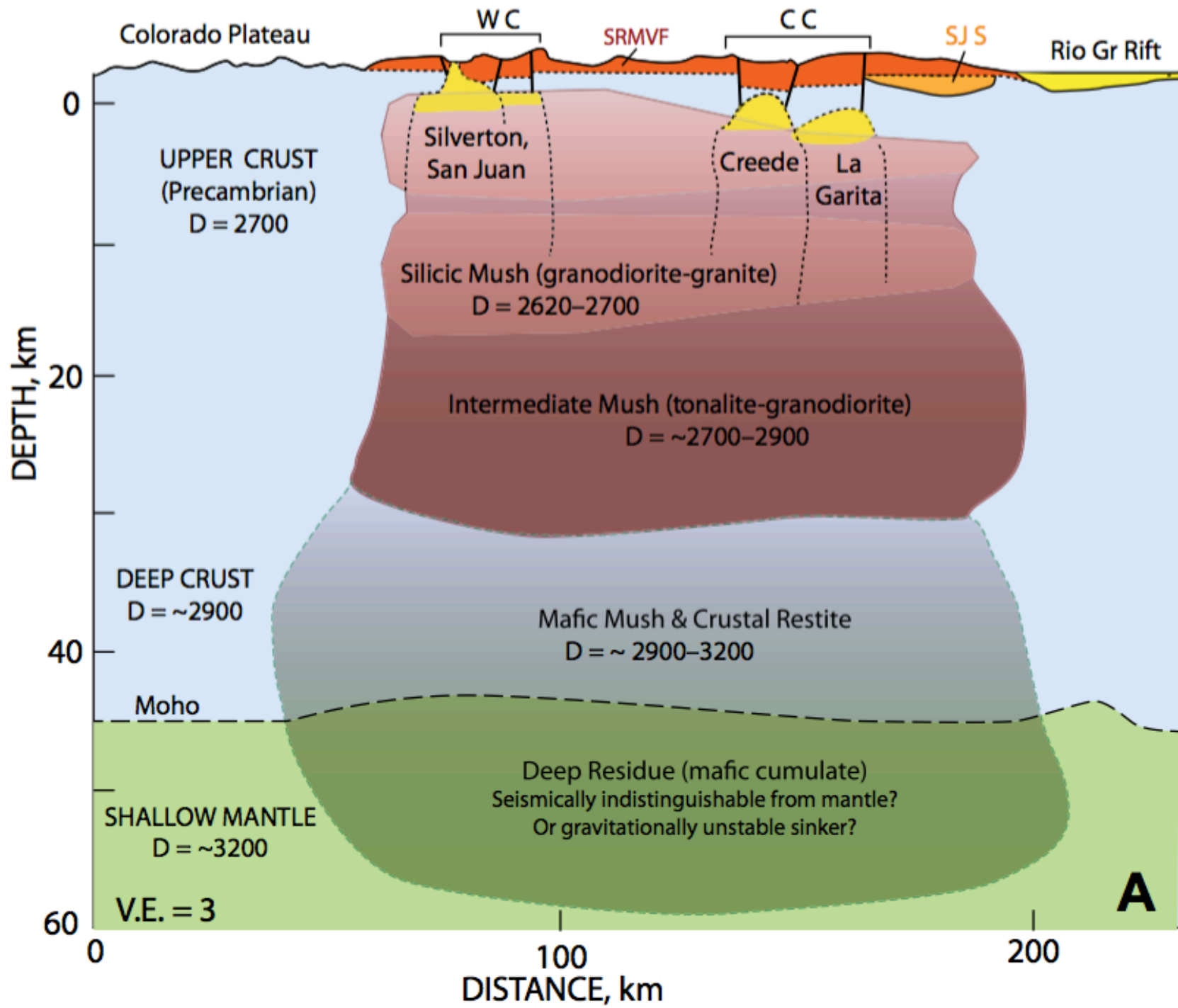
- Remelting of earlier intrusions by later basalt injections

- Fractional crystallization of hydrous basalt (potentially lots of H₂O, low viscosity)

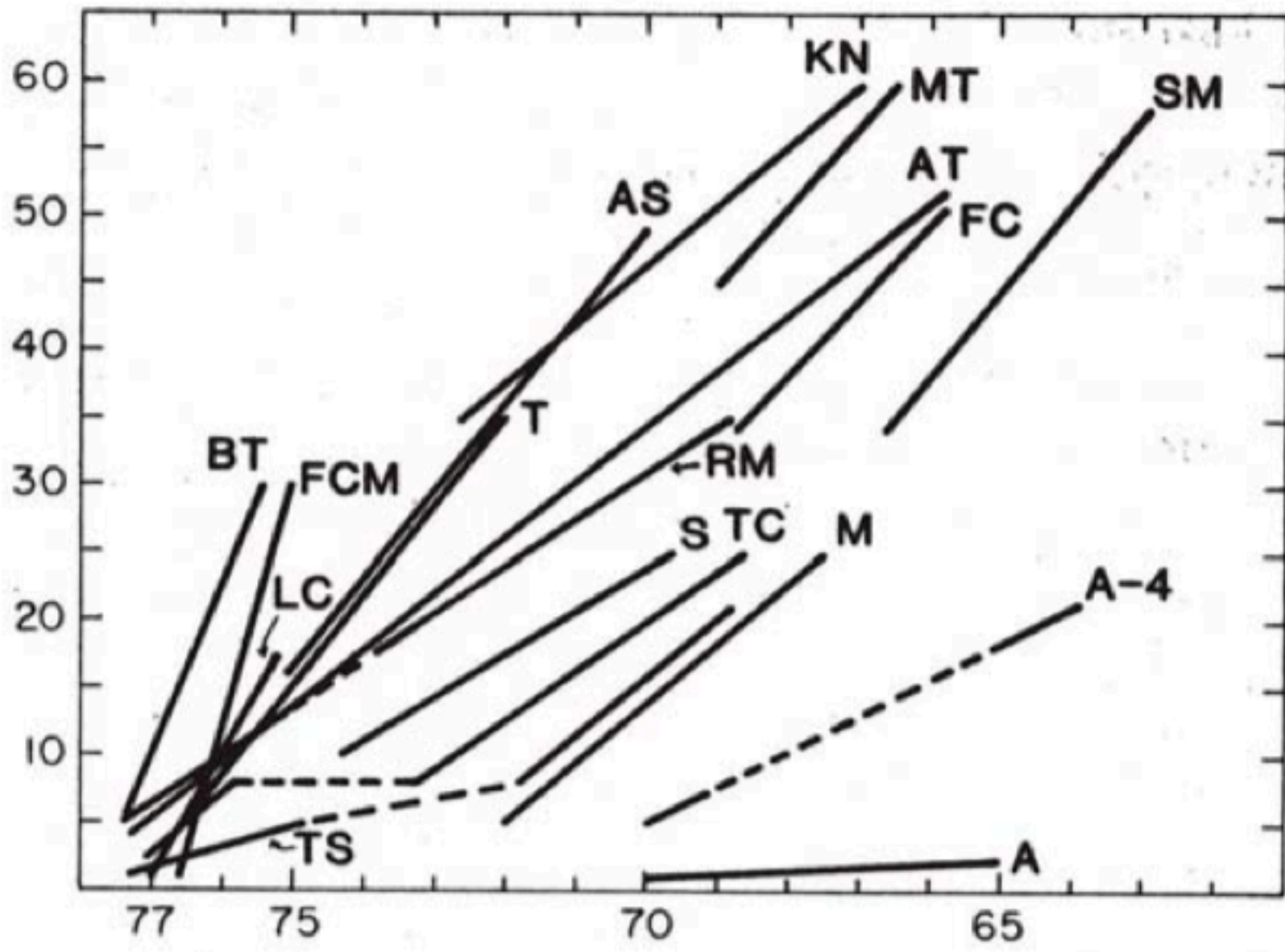
Think about:

- Combinations of the above
- Differences in physical properties and rheology of the liquids produced
- Chemical and isotopic signatures





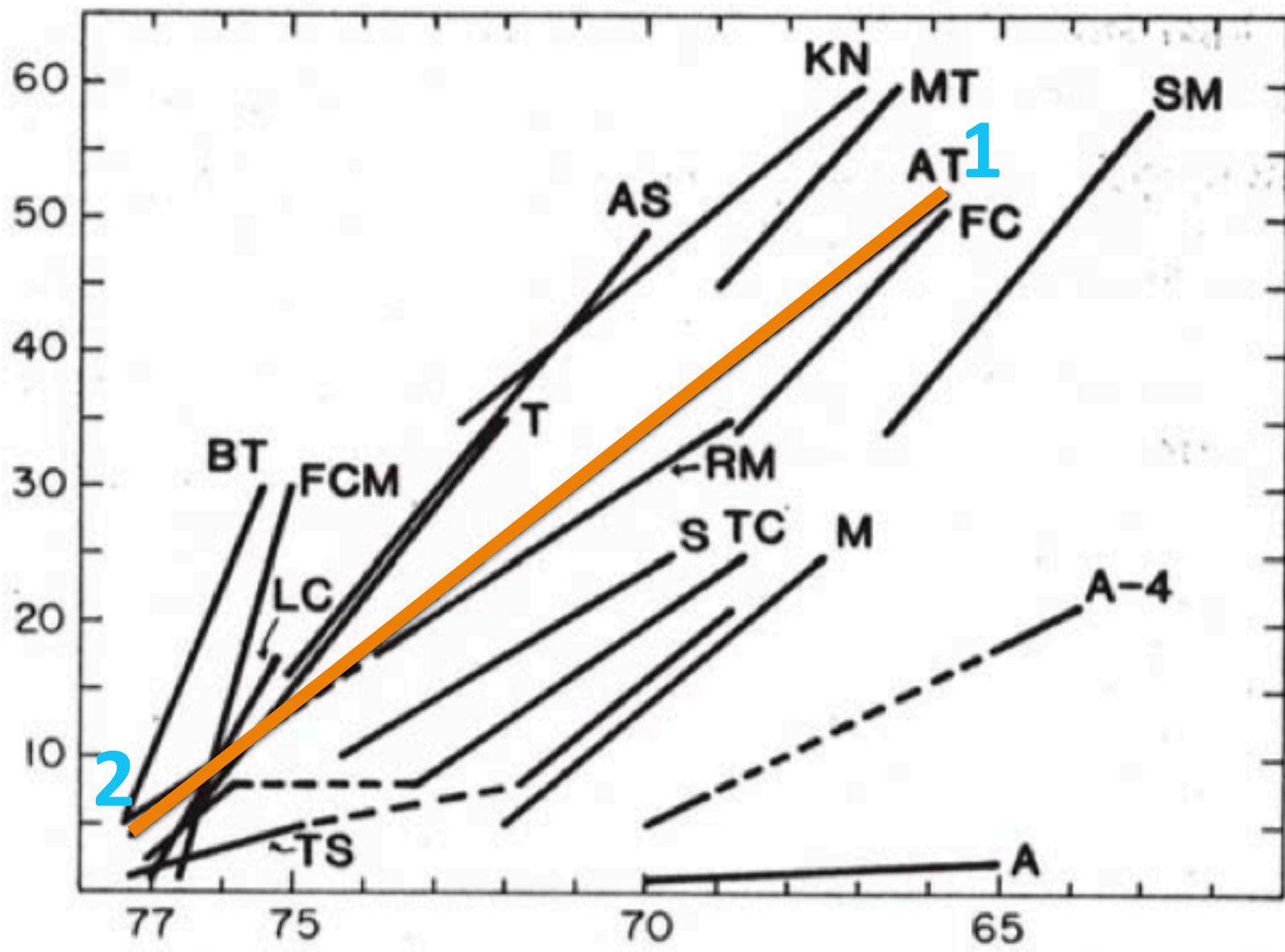
VOLUME % PHENOCRYSTS



Wt. % SiO₂

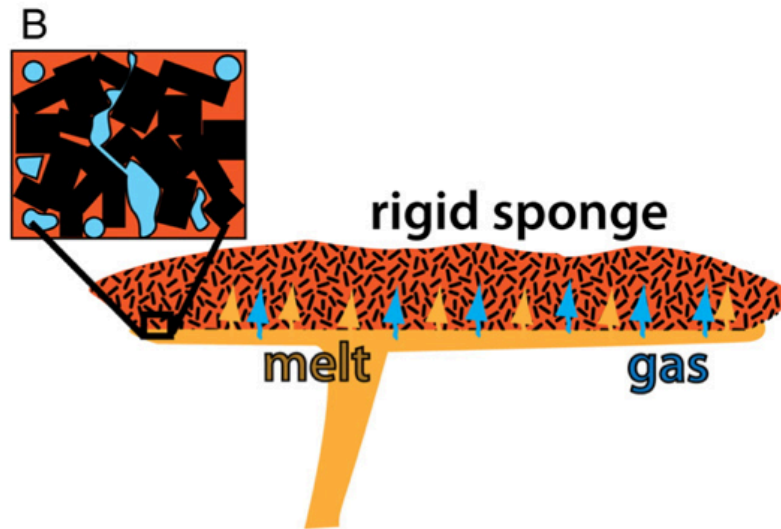
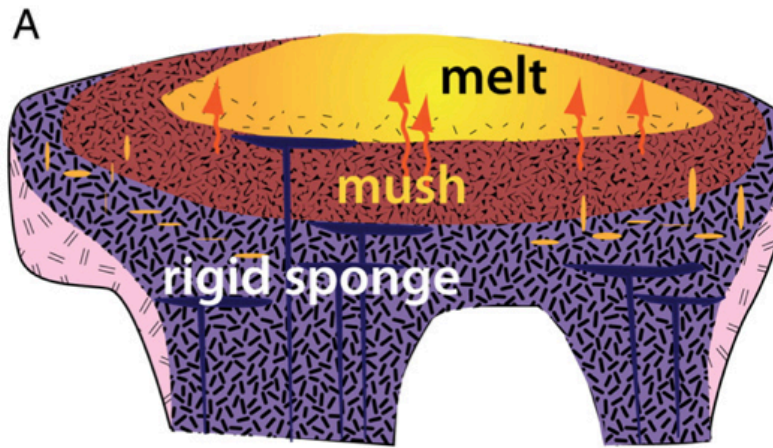
A

VOLUME % PHENOCRYSTS



Wt. % SiO₂

A



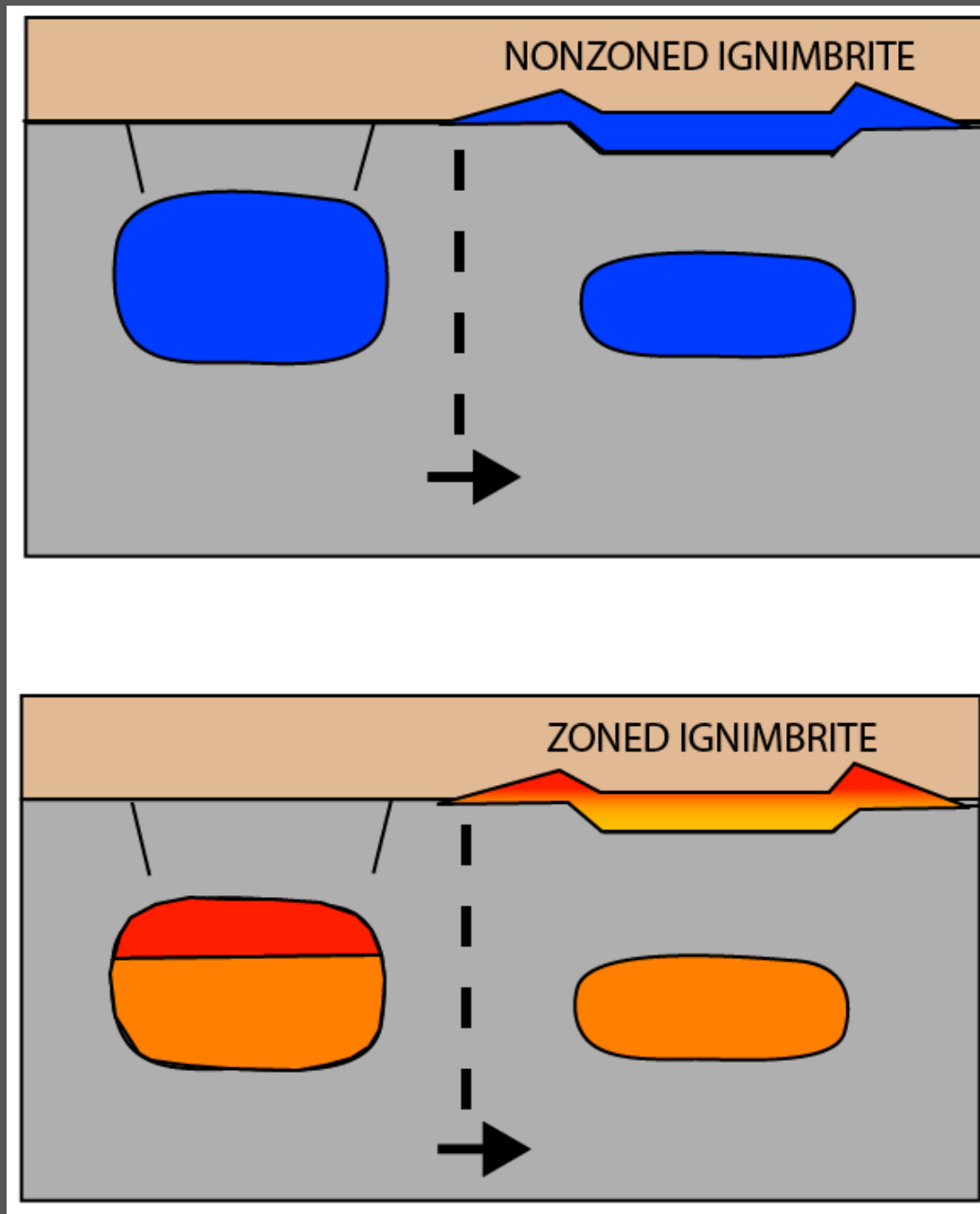
Crater Lake caldera – Magma zonation



Late Erupted - Dacite

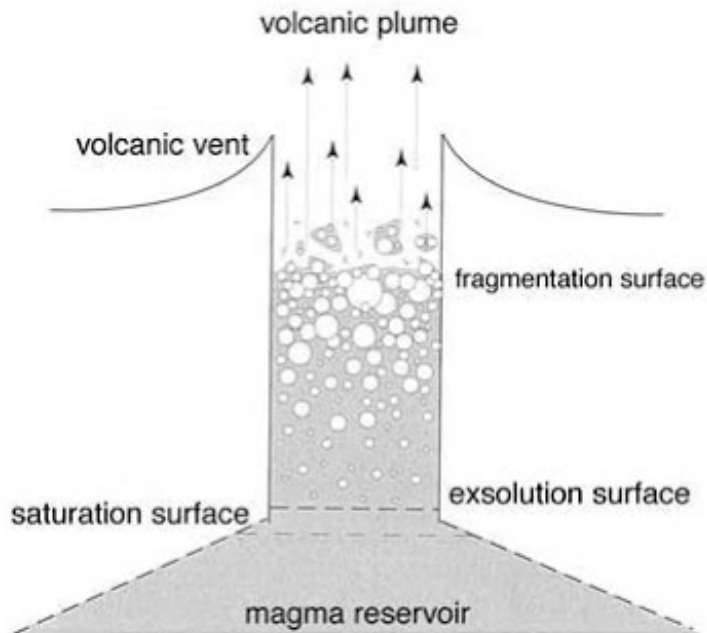
Early Erupted - Rhyolite

Why did the eruption stop?

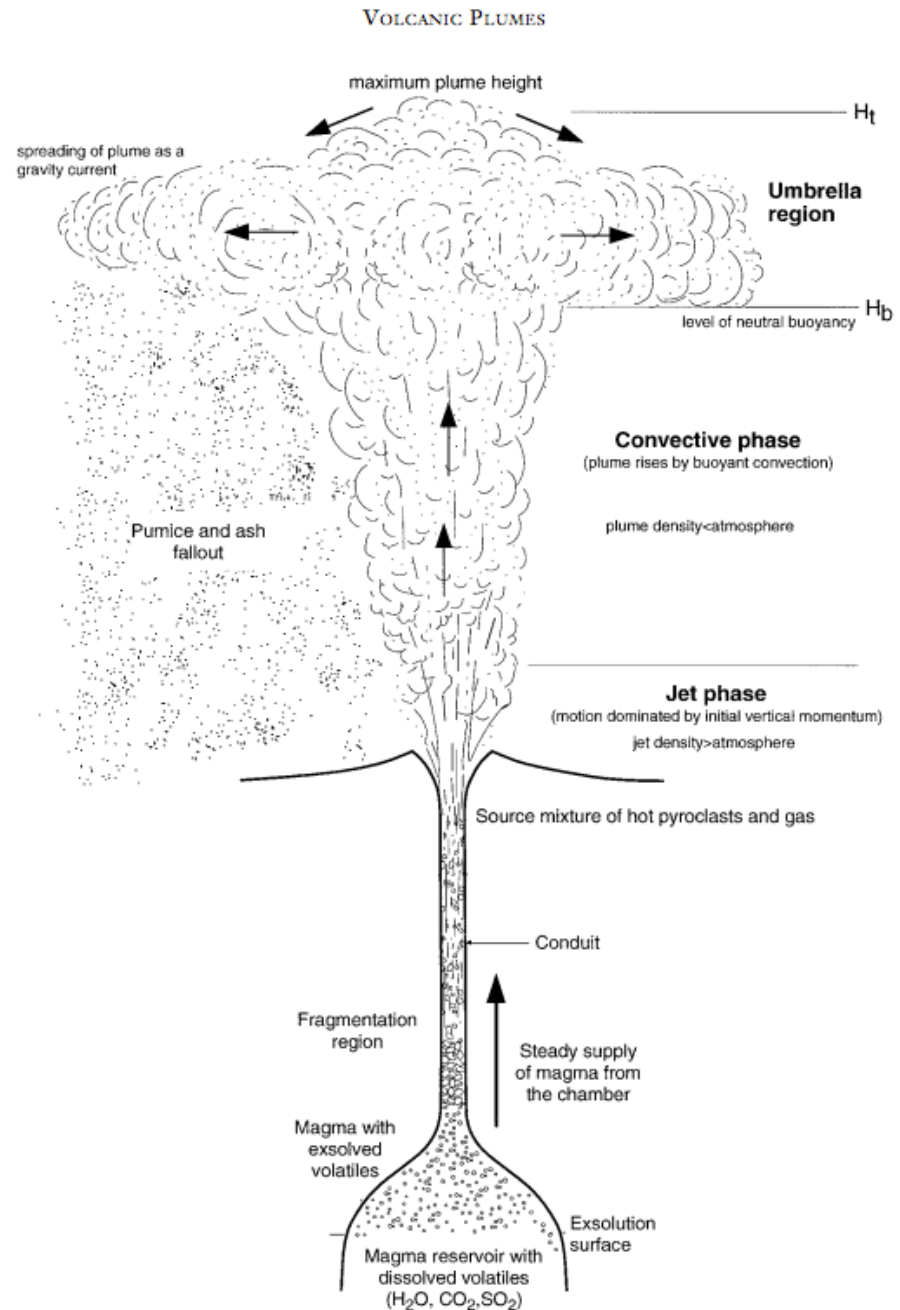


Lipman et al., 1978

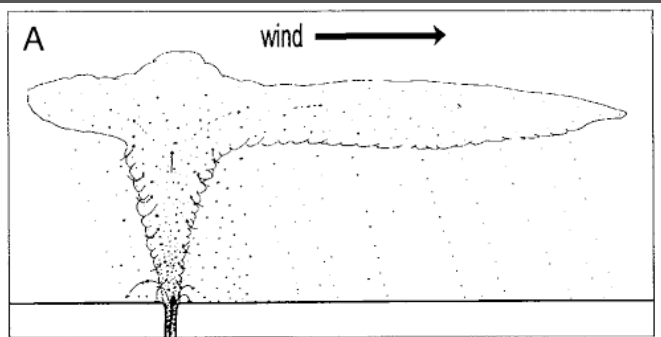
Components and emplacement of caldera-forming eruptions



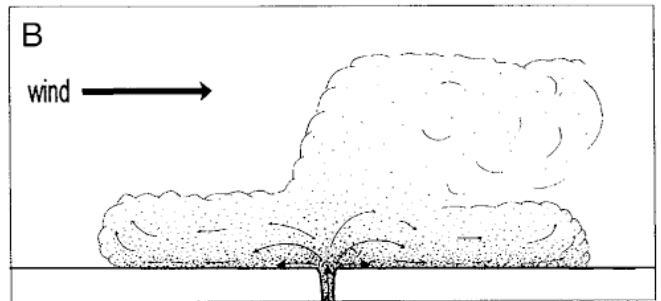
Components in eruptive plume?



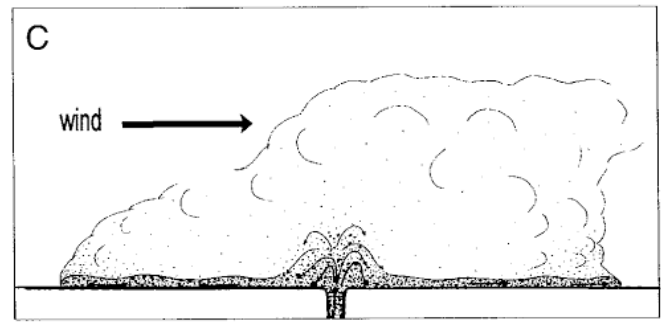
Pyroclastic Deposits



Fall Deposits

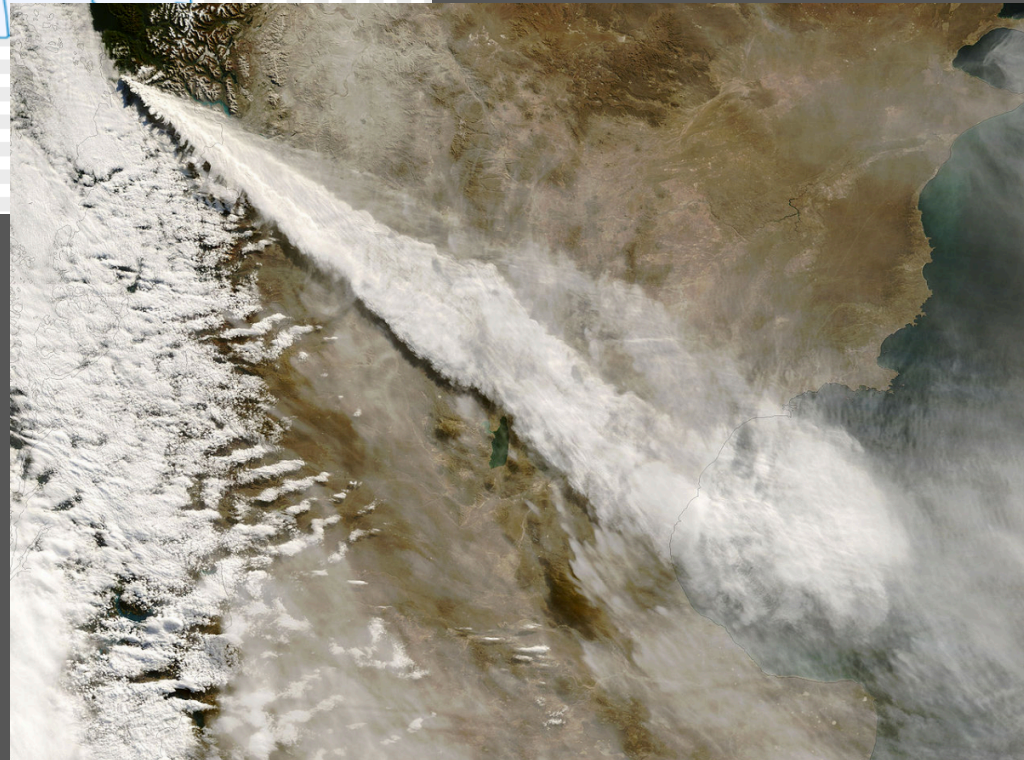
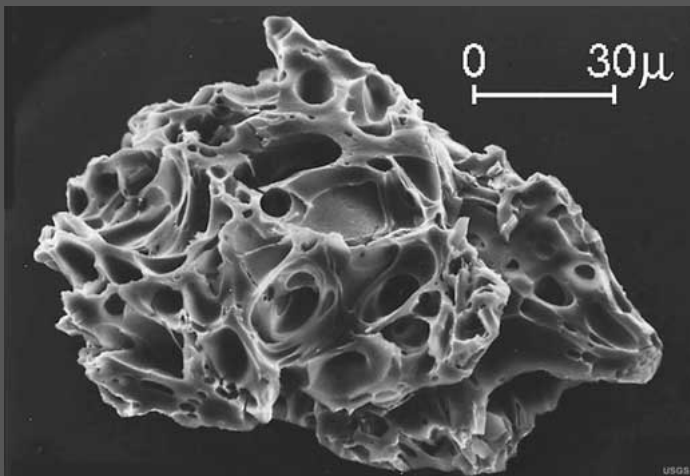
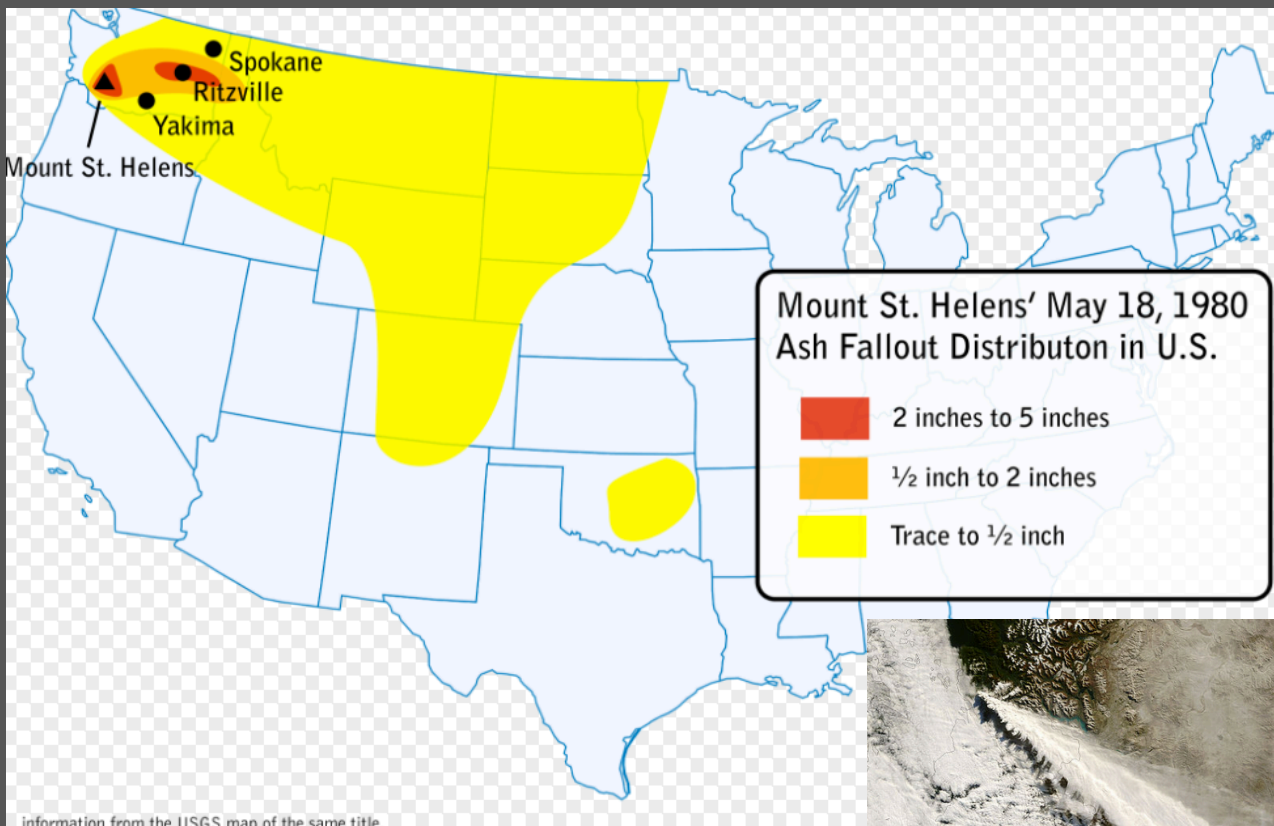


Surge Deposits



Flow Deposits

Fall Deposits



Fall Deposits

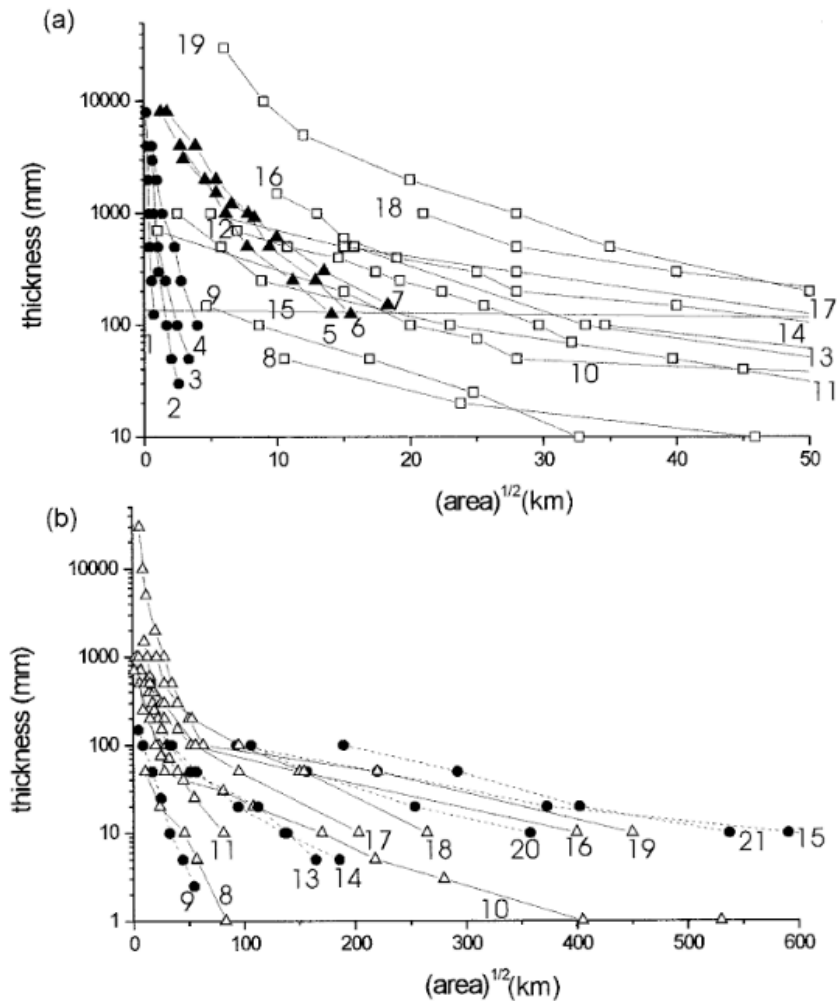


FIGURE 3 Plots of $\ln T$ versus \sqrt{A} . (a) Plot of proximal thinning relationships for representative hawaiian/strombolian (solid circles), subplinian (solid triangles), and plinian/phreatoplinian (open squares) tephras. (b) Similar plot at expanded scale for the plinian (open triangles; solid line) and phreatoplinian (solid circles; dashed line) units.

Fall Deposits



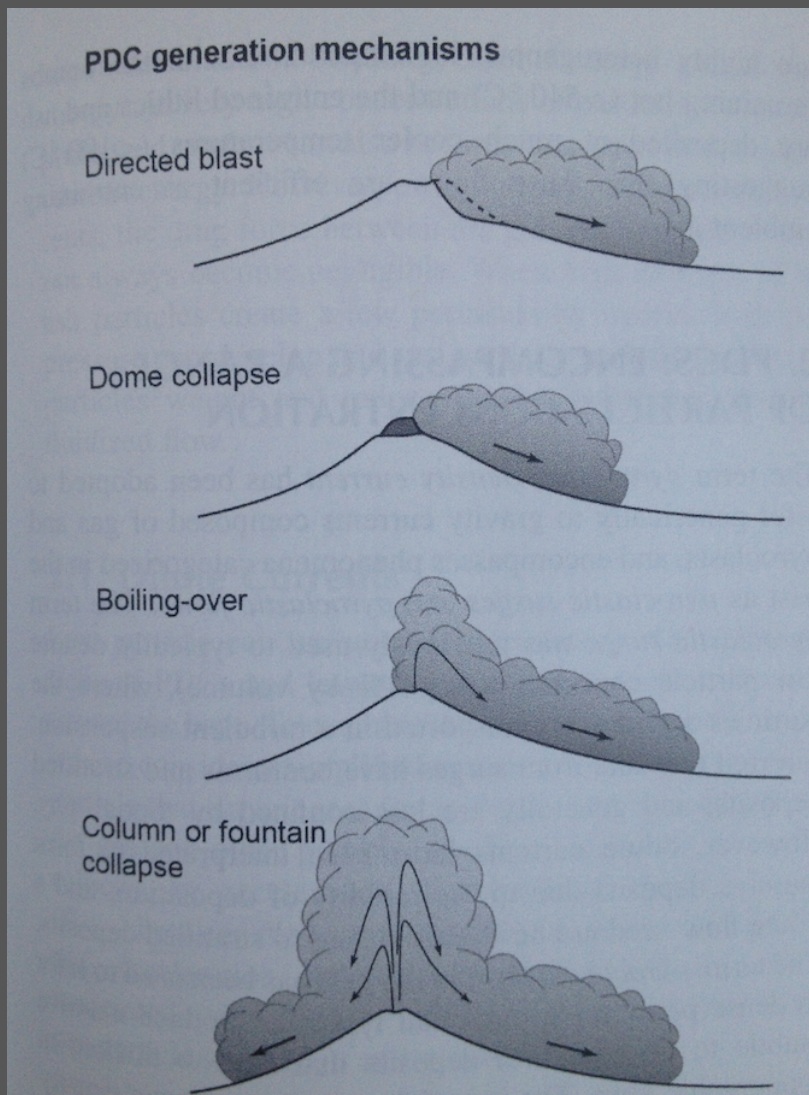
Fall Deposits



Fall Deposits

- 1 – Mantle topography
(just like snow)
- 2 – Individual deposits are well sorted
- 3 – Graded beds
(changing in wind direction, eruption intensity)

Plume Collapse and Pyroclastic Density Currents (PDCs)



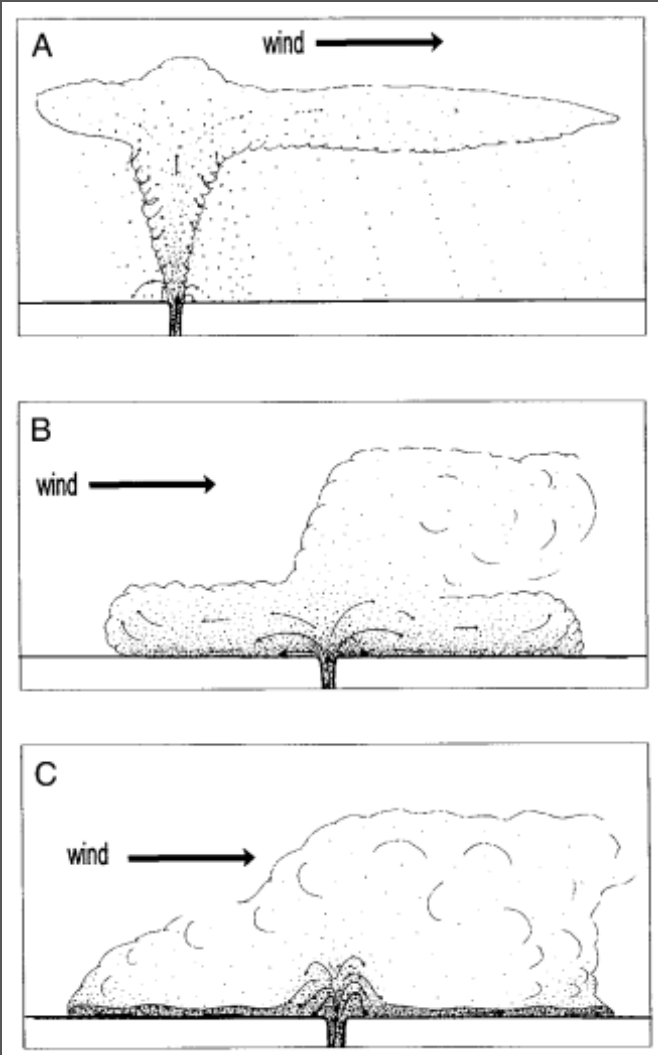
Small volume – postcaldera domes

Small volume – postcaldera domes

Low eruption rate

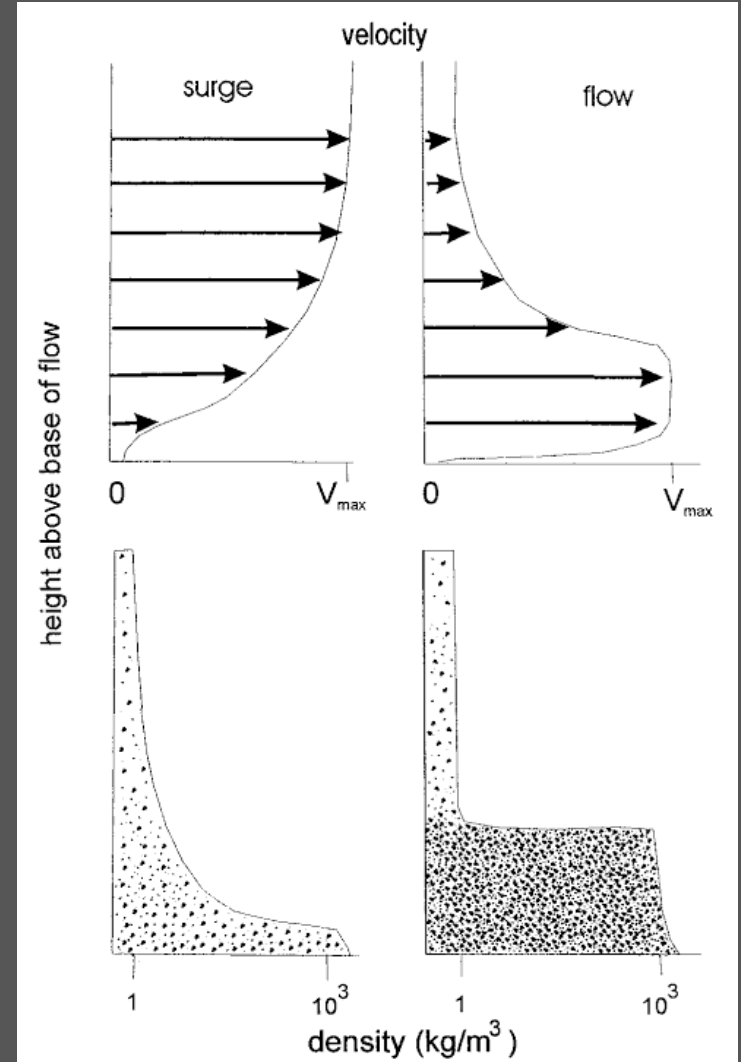
Most relevant to large calderas

Pyroclastic Density Currents (Surge and Flow)



surge

flow



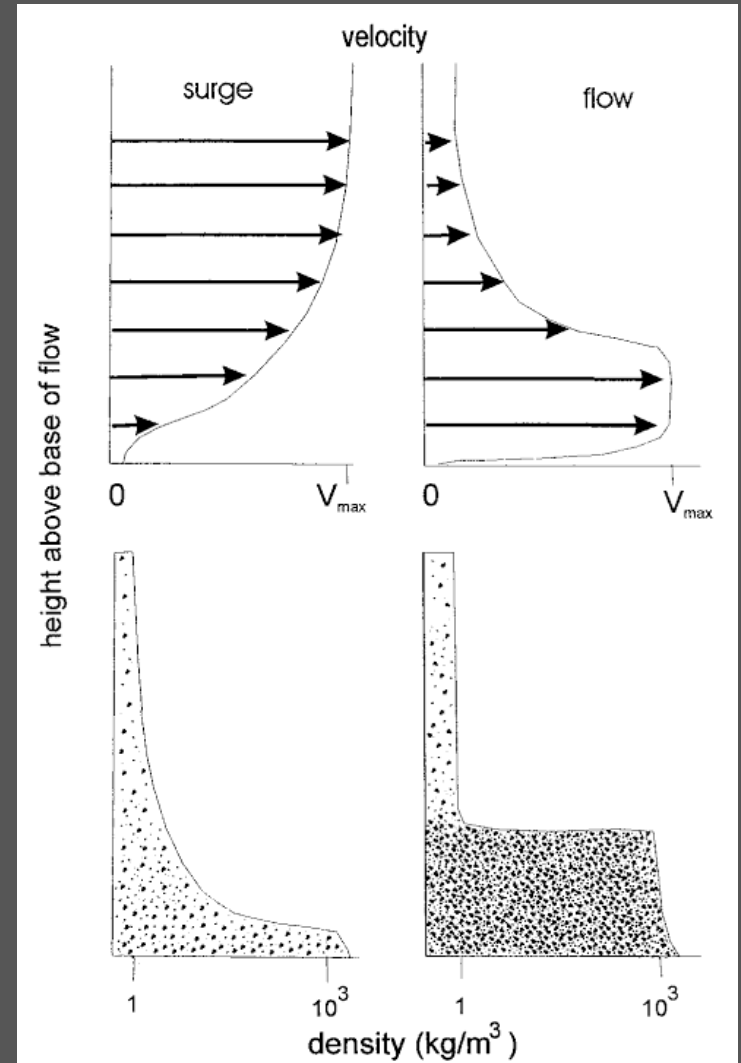
Pyroclastic Density Currents (Surge and Flow)

SURGE

- Dilute (gas \gg particles)
- Turbulent Flow
- Small-volume

FLOW

- Concentrated (solids \gg fluid)
- ~Laminar Flow
- Large-volume



Pyroclastic Surges

Cross-bedding

Dunes

Well to moderately sorted
(less than fall; more than flow)

Some grain size variation
(few fines and coarse material)

Thin to thick beds
(< 10 cm to several m)

Volumetrically Minor



Pyroclastic Surges



Pyroclastic flows (ignimbrite)



Pyroclastic flows (ignimbrite)

Bedded to Massive

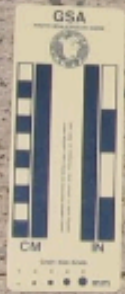
Poorly sorted

Graded

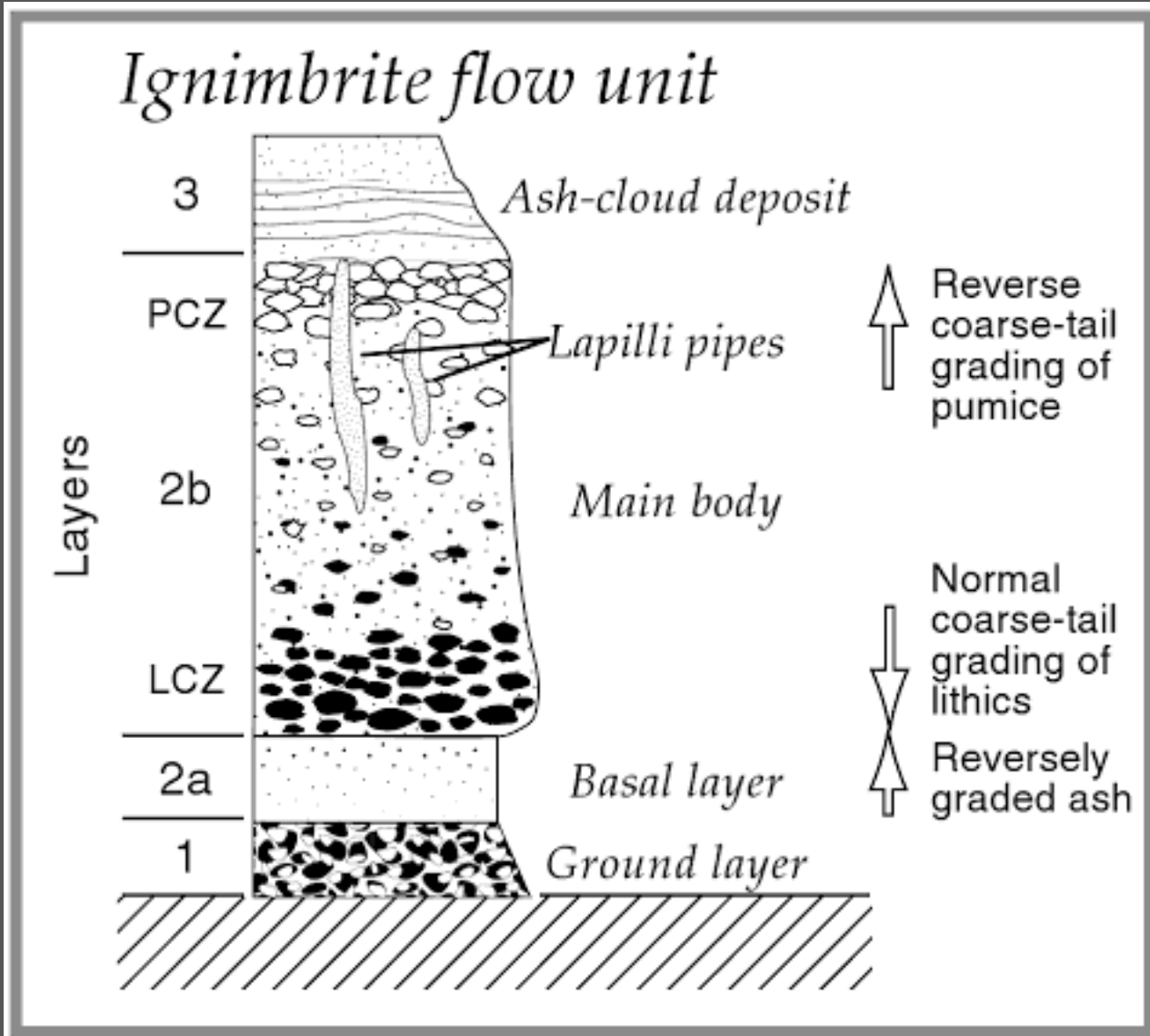
Large grain size distribution
(< 1 mm as to $\gg 1$ m blocks)

Emplaced into topographic lows
“flows follows lows”

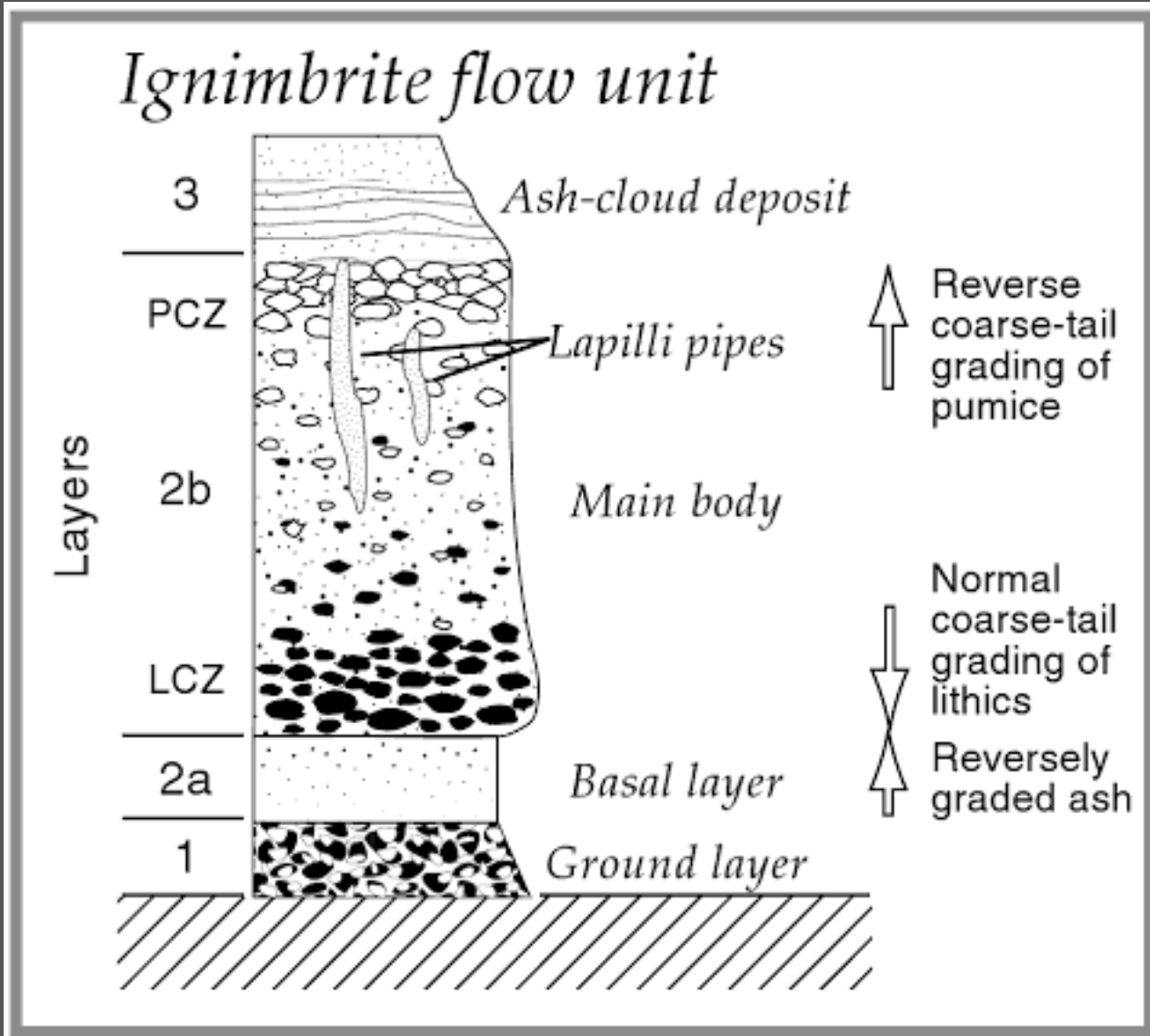




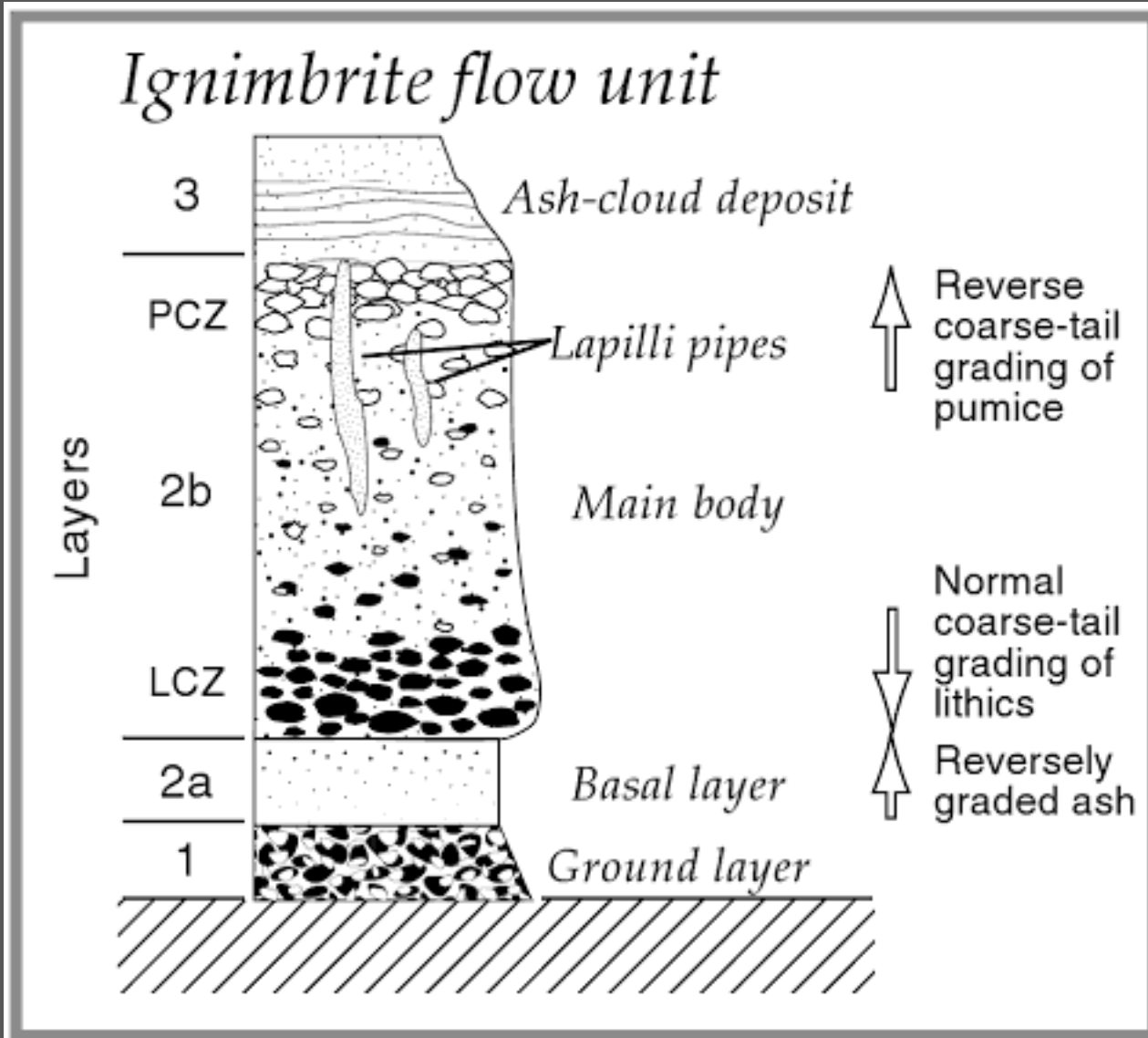
Ignimbrite Stratigraphy



Ignimbrite Stratigraphy



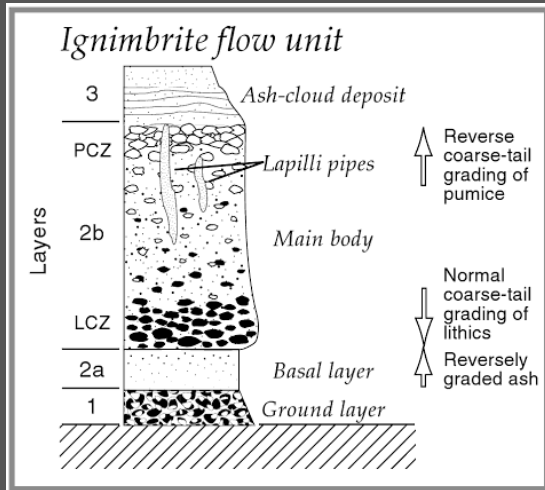
Ignimbrite Stratigraphy



Layer 2b –

Graded
(lithics on sink
and pumice floats)

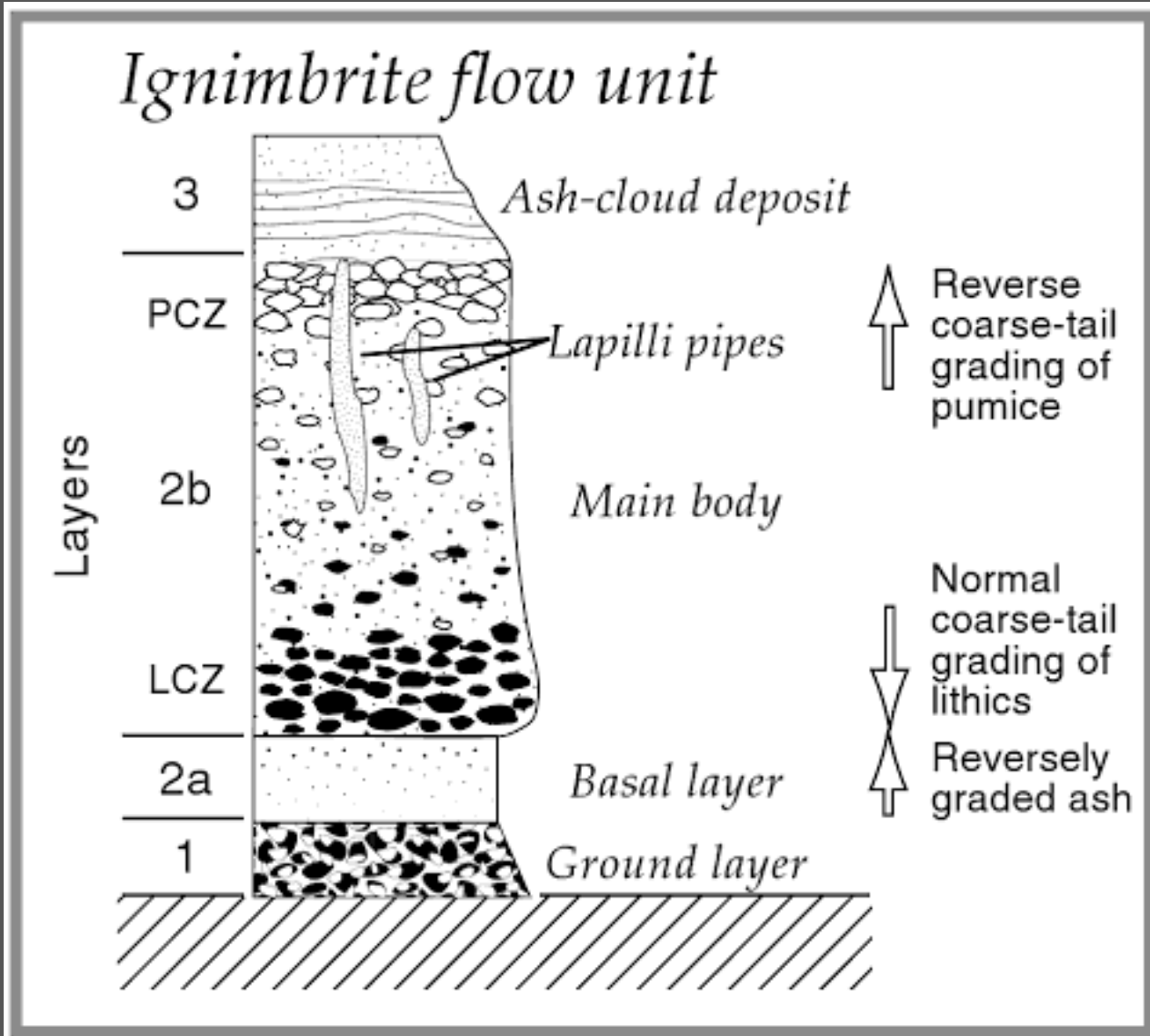
Ignimbrite Stratigraphy



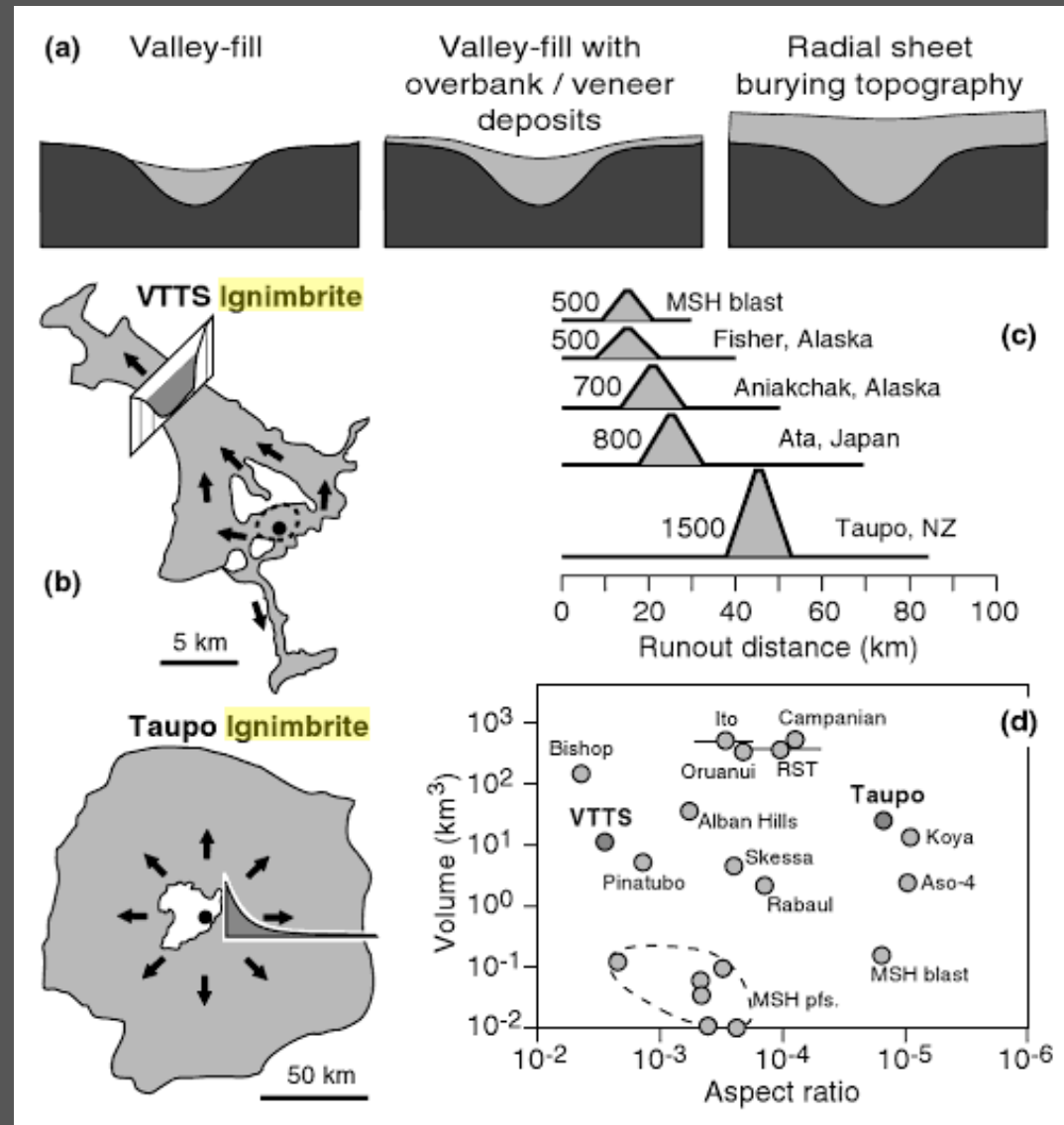
Lithics “sink”

Pumice “floats”

Ignimbrite Stratigraphy



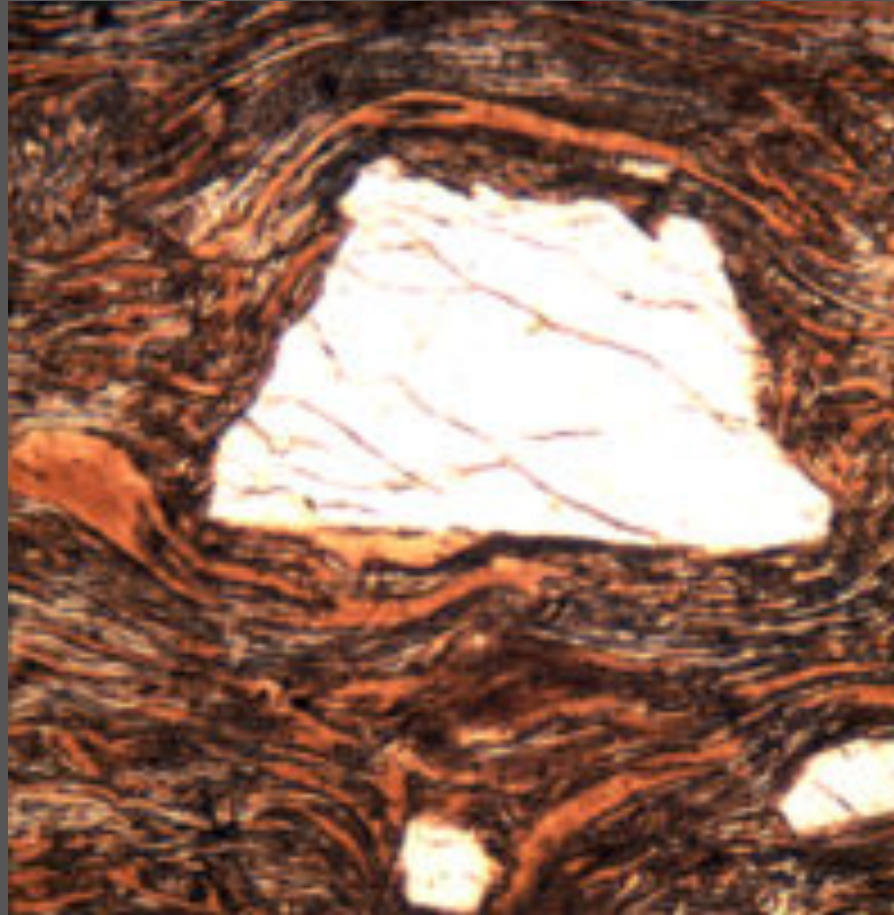
Ignimbrite Distribution



Welding of Ignimbrites



Welding of Ignimbrites



Rheomorphic flow of ignimbrite



Ductile flow after emplacement

Welding and Devitrication Zones within Ignimbrites

